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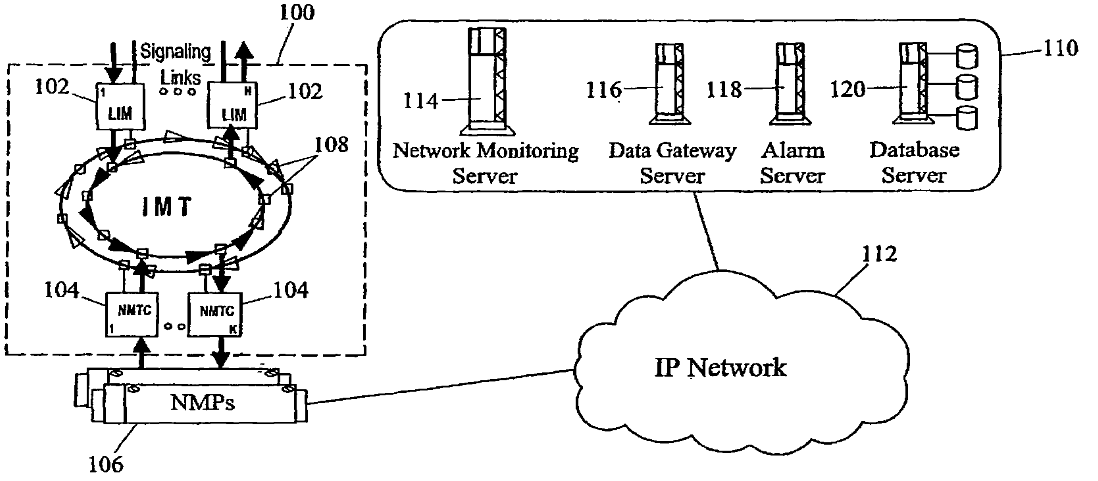
(54) Title: METHODS AND SYSTEMS FOR AUTOMATICALLY CONFIGURING NETWORK MONITORING SYSTEM



(57) Abstract: An automatically configurable network monitoring system includes a network monitoring communications protocol used for communications between a network monitoring client executing on a routing node (100) being monitored and a network monitoring server executing on a network monitoring processor (106). According to the network monitoring communications protocol, the network monitoring client broadcasts a network monitoring service request message to the network monitoring servers. The service request messages identifies a signaling link for which network monitoring service is being requested. The network monitoring servers provisioned to the requested provide network monitoring service respond affirmatively and thereby automatically grant network monitoring service. The network monitoring system may be completely probeless or, alternatively, used in conjunction with probe-based network monitoring devices.

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Description

METHODS AND SYSTEMS FOR AUTOMATICALLY CONFIGURING NETWORK MONITORING SYSTEM

Related Applications

This application claims the benefit of United States provisional patent application number 60/293,328, filed May 23, 2001, the disclosure of which is incorporated herein by reference in its entirety

Technical Field

The present invention relates to network monitoring system. More particularly, the present invention relates to a methods and systems for automatically configuring a network monitoring system.

Background Art

In telecommunications signaling networks, network monitoring systems are used to perform various functions, such as call tracing, billing, billing verification, fraud detection, protocol verification, etc. In order to perform these functions, network monitoring devices copy signaling messages from signaling links and process these messages into a useful format, such as a transaction record. One conventional method for copying signaling messages is to place link probes on signaling links connected to signaling message routing nodes, such as signal transfer points. The link probes are typically connected to a monitoring unit that processes the copied signaling messages.

One disadvantage of using link probes and an external monitoring unit to copy and process signaling messages is that these devices take up space in telecommunications network facilities. Since these facilities are often located in urban buildings where space expensive, using external link probes and monitoring units may be undesirable.

In order to reduce the space required to perform network monitoring functions, hybrid network monitoring systems have been developed. These hybrid monitoring systems typically involve a copy function located within a routing node for copying signaling messages, one or more computers outside of the routing node for processing the signaling messages, and external link probes and monitoring devices for some of the signaling links connected to the routing node. Because the copy function is located within the routing node, the need for external link probes is reduced. However, even these hybrid systems required some external link probes to capture all of the signaling messages received by or sent from the routing node being monitored.

One disadvantage of conventional network monitoring systems is that these systems must be manually configured to match the configuration of the routing node being monitored. For instance, signaling links connected to signal transfer points are taken in and out of service on a daily basis. The monitoring system, in both the hybrid and probe-based cases, must be manually reconfigured each time the configuration of the network being monitored changes. When a link is taken out of service, the monitoring system must be reconfigured to cease monitoring the out of service link. When a new link is put in service, the monitoring system must be reconfigured to monitor the new link.

Adding a signaling link to a signal transfer point typically includes adding a new printed circuit board to the signal transfer point and connecting the printed circuit board to an external cable. In the probe-based case, re-configuring the network monitoring system includes attaching a new link probe to the cable and programming the monitoring unit to recognize signaling messages on the new signaling link. For hybrid network monitoring systems that include internal and external link monitors, both new link probes and internal signaling message copy functions may require modification. Such manual reconfiguration is both time and labor intensive and often results in the network monitoring system being out of sync with the network being monitored.

In light of the difficulties associated with conventional network monitoring systems, there exists a long felt need a network monitoring system with reduced configuration time.

Disclosure of the Invention

The present invention includes methods and systems for automatically configuring a network monitoring system. According to one aspect, an automatically configurable network monitoring system includes a plurality of link interface modules associated with external signaling links. When a link interface module in a routing node boots up and begins to service a signaling link, the link interface module requests network monitoring service from a group of network monitoring applications. The network monitoring applications are pre-associated with subsets of the total set of signaling links that could be serviced by with the routing node. The network monitoring application associated with the link interface module accepts requesting service the request. A network monitoring session is established between the link interface module and the network monitoring application. The link interface module sends signaling messages copied from the signaling link over the session. If the link interface module is taken out of service, the network monitoring session ends and resources on a network monitoring processor on which the network monitoring application executes previously dedicated to the link interface module are available to monitor other signaling links. Because a network monitoring system according to the present invention automatically adapts itself to monitor new signal links and to cease monitoring signaling links that are taken out of service, the amount of labor required to reconfigure a network monitoring system is greatly reduced over conventional network monitoring configuration methods.

Accordingly, it is an object of the present invention to provide an automatically configurable network monitoring system.

It is another object of the invention to provide a method for automatically configuring a network monitoring system.

It is another object of the invention to provide a completely probeless network monitoring system.

Some of the objects of the invention having been stated hereinabove, other objects will become evident as the description proceeds when taken in connection with the accompanying drawings as best described hereinbelow.

Brief Description of the Drawings

Preferred embodiments of the invention will now be explained with reference to the accompanying drawings, of which:

Figure 1 is a block diagram of an automatically configurable network monitoring system according to an embodiment of the present invention;

Figure 2 is a block diagram of a processing module including exemplary hardware suitable for use in an automatically configurable network monitoring system according to an embodiment of the present invention;

Figure 3 is a schematic diagram of a telecommunications equipment frame including an automatically configurable network monitoring system according to an embodiment of the present invention;

Figure 4 is a schematic diagram of a plurality of network monitoring processors connected via an Ethernet according to an embodiment of the present invention;

Figure 5 is a schematic diagram of a plurality of telecommunications equipment racks holding a routing node and a plurality of network monitoring processors according to an embodiment of the present invention;

Figure 6 is a protocol layering and software diagram illustrating exemplary protocol layers and software components of an automatically configurable network monitoring system according to an embodiment of the present invention;

Figure 7 is a flow chart illustrating exemplary overall steps of a method for automatically configuring a network monitoring system according to an embodiment of the present invention;

Figure 8 is a message flow diagram illustrating exemplary messages exchanged between a network monitoring client and a network monitoring processor in establishing and maintaining an alarm session according to an embodiment of the present invention;

Figure 9 is a message flow diagram illustrating exemplary messages exchanged between a network monitoring client and a network monitoring processor in establishing and maintaining a link data session according to an embodiment of the present invention;

Figure 10A is a state diagram illustrating an exemplary network monitoring client state machine according to an embodiment of the present invention;

Figure 10B is a state diagram illustrating an exemplary provisioning manager state machine according to an embodiment of the present invention;

Figure 10C is a state diagram illustrating an exemplary application handler state machine according to an embodiment of the present invention;

Figure 11 is a message format diagram illustrating a generic format for a network monitoring communications protocol message suitable for use by embodiments of the present invention;

Figure 12 is a message format diagram illustrating an exemplary format for a heartbeat message suitable for use by embodiments of the present invention;

Figure 13 is a message format diagram illustrating an exemplary format for a service request message suitable for use by embodiments of the present invention;

Figure 14 is a message format diagram illustrating an exemplary format for a service accept message suitable for use by embodiments of the present invention;

Figure 15 is a message format diagram illustrating an exemplary format for a service reject message suitable for use by embodiments of the present invention;

Figure 16 is a message format diagram illustrating an exemplary format for a provisioning information message suitable for use by embodiments of the present invention;

Figure 17 is a message format diagram illustrating an exemplary format for an event message suitable for use by embodiments of the present invention;

Figure 18 is a message format diagram illustrating an exemplary format for a link data message suitable for use by embodiments of the present invention;

Figure 19 is a message format diagram illustrating an exemplary format for a service change message suitable for use by embodiments of the present invention; and

Figure 20 is a network diagram illustrating exemplary deployment of an automatically configurable network monitoring system according to an embodiment of the present invention.

Detailed Description of the Invention

System Overview

In one embodiment, an automatically configurable network monitoring system according to the present invention may integrated within a network routing node, such as a signal transfer point or an SS7/IP gateway. Figure 1 illustrates an exemplary architecture for an integrated automatically configurable network monitoring system according to an embodiment of the present invention. In Figure 1, reference numeral **100** represents a routing node, such as an STP or an SS7/IP gateway. Routing node **100** includes a plurality of link interface modules (LIMs) **102** that send and receive SS7 messages via SS7 signaling links. Although not illustrated in Figure 1, routing node **100** may also include data communication modules (DCMs) for sending and receiving IP messages via IP signaling links. Network monitoring transport cards (NMTCs) **104** route messages between LIMs **102** and network monitoring processors (NMPs) **106**. LIMs **102** and NMTCs **104** are connected via IMT buses **108**. NMPs **106** buffer MSUs and alarm messages received from routing node **100**.

From a software perspective, LIMs **102** include TCP/IP protocol stack software for establishing TCP/IP connections with NMPs **106** through NMTCs **104**, network monitoring client software for requesting network monitoring services from NMPs **106**, MSU copy functions for copying incoming and outgoing MSUs, and SS7 alarm functions for generating alarm notifications when certain events, such as signaling link failures, occur. LIMs **102** encapsulate MSUs and alarm notifications in specialized packets that indicate the source of the MSUs or alarm messages. LIMs **102** also communicate provisioning information to NMPs **106** to enable automatic configuration of NMPs **106** when a signaling link is added or deleted.

NMPs **106** execute server software that responds to service requests from LIMs **102**. The server software on each NMP **106** may be associated with a predetermined set of signaling links. For example, server software on NMP **106** may be provisioned to handle signaling links 0-31 and server software on another NMP **106** may be provisioned to handle signaling links 32-63 in a routing node wired for 64 total possible signaling links, even if the routing node is not equipped for 64 links. As used herein, the term "equipped link" refers to a signaling link for which a link interface module is present in a routing node and in service. The term "wired link" refers to a link in a routing node for which no link interface card is present but wiring for such a card is present. A wired link becomes an equipped link when a link interface module is plugged into the corresponding card slot.

Because network monitoring processors **106** include software that is pre-provisioned to service all of the links in a routing node, regardless of whether the links are wired or equipped, network monitoring processors **106** automatically adapt to changes in configuration of the routing node. For example, as will be explained in detail below, when a LIM boots up with the network monitoring client software enabled, the LIM broadcasts a service request message to network monitoring processors **106**. The server software on NMPs **106** provisioned to handle the request for that particular LIM responds to the request. If the response is a service acceptance, the requesting LIM establishes a TCP/IP connection with the responding server and begins sending network monitoring messages to the server. The server on NMP **106** receives and buffers the received messages.

NMPs **106** communicate with a server farm **110** via IP network **112**. In the illustrated example, server farm **112** includes a network monitoring server **114**, a data gateway server **116**, an alarm server **118**, and a database server

120. Network monitoring server **114** performs the following functions: real time signaling link status reporting, real time signaling link state reporting, real time protocol analysis, such as call tracing, filtering, and decoding, traffic report generation, CDR generation and real time event reporting. Data gateway server **116** receives MSU fragments, formats the MSU fragments into CDRs and sends the CDRs to applications, such as fraud detection applications, billing verification applications, etc. Alarm server **118** collects event message reports and other events that report signaling link errors and displays alarms to the user. Database server **120** is connected to network monitoring server **114**. Network monitoring server **114** generates predefined traffic reports in flat ASCII format. Some end users may desire to generate customized traffic reports. Hence, database server **120** stores the data collected by network monitoring server **114** in a database, such as an Oracle database. A database front end, such as Crystal Reports available from Seagate Software may be used along with database server **120** to generated customized reports.

System Hardware and Physical Configuration

From a hardware perspective, each LIM **102** and NMTC **104** may be implemented using an application processor card. Figure 2 illustrates an example of an application processor card suitable for use as LIMs **102** and NMTCs **104**. In Figure 2, application processor card **200** includes an application processor **202** and a communication processor **204**. Application processor **202** may be a general purpose microprocessor that executes one or more application programs. In the illustrated example, application programs **206** that execute on application processor **202** may include an SS7 link interface applications in the case where application processor card **200** functions an SS7 link interface module, an SS7 over IP application in the case where application processor card **200** functions as an SS7/IP conversion module, or a network monitoring transport application in the case where application processor card **200** functions as a network monitoring transport card.

Communication processor **204** may be a microprocessor programmed to send and receive message via buses **108**. A dual port memory **208** is shared by application processor **202** and communication processor **204**. For example, when application processor **202** wishes to send a message via buses **108**, application processor **202** may write the message into dual port memory **208**. Communication processor **204** may read the message from dual port memory **208** and place the message on one of buses **108**. Application processor card **200** may also include physical layer hardware **210** for interfacing with an external network. For example, physical layer hardware **210** may include electrical or optical interface physical layer and framer chips for sending and receiving bits to and from an external network.

Network monitoring processors **106** illustrated in Figure 1 may be implemented using application processor cards, such as application processor card **200** illustrated in Figure 2. However, because network monitoring processors **106** are likely to receive a high volume of network monitoring traffic from many different application processor cards, network monitoring processors **106** are preferably configured to receive these messages via a different medium than buses **108** in order to avoid congestion on buses **108**. Figure 3 illustrates an embodiment of the present invention in which network monitoring processors **106** are implemented as rack-mountable general purpose computers connected to network monitoring transport cards **104** via one or more switches or hubs. In Figure 3, a telecommunications equipment frame **300** may include racks or shelves for carrying application processor cards **200**, network monitoring processors **106**, and interconnecting switches and routers.

In the illustrated example, application processor cards **200** are located on a first shelf of frame **300**. Application processor cards may include network monitoring transport cards **104**, other cards **302**, and one or more empty card slots **304**. Other cards **302** may be any type of application processor cards, including SS7 link interface modules for sending and receiving messages via external SS7 signaling links, SS7/IP data communication modules for sending and receiving SS7 messages over an IP network, or database service modules for performing database-related functions, such as global title and number portability translations.

Network monitoring processors **106** are located in the next two racks of equipment frame **300**. In the illustrated example, network monitoring processors **106** are rack mountable general purpose computers. An example of a rack mountable general purpose computer suitable for use as network monitoring processors **106** is the Netra T1 DC200 available from SUN Microsystems. Network monitoring processors **106** are preferably configured as a n+1 redundant configuration for reliability purposes.

Switches **306** redundantly connect network monitoring processors **106** to network monitoring transport cards **106**. For example, in a preferred embodiment of the invention, switches **306** comprises Ethernet switches for connecting network monitoring processors **106** with network monitoring transport cards **104** via redundant Ethernet connections. Figure 4 illustrates in more detail the connection of network monitoring processors **106** and network monitoring transport cards **104**. In the illustrated example, a first Ethernet switch **306A** interconnects network monitoring processors **106** to each other and to network monitoring transport cards **104** via a Ethernet connections **400** and **402**. Similarly, a second Ethernet switch **306B** interconnects network monitoring processors **106** to each other and to network monitoring processor cards **104** via Ethernet connections **406** and **408.** Redundantly connecting network monitoring processors **106** and network monitoring transport cards **104** decreases the likelihood that network monitoring messages will be lost in the event of a card or card interconnection failure.

Figure 5 illustrates and example of a multi-rack routing node including an automatically configurable network monitoring systems according to an embodiment of the present invention. In Figure 5, routing node **500** includes a first frame **502** for holding network monitoring processors **106**, network monitoring transport cards **104**, and switches **306**. Slots **503** in frame **502** are empty and provide the capability to add addtional network monitoring transport cards **104**. Frame **504** includes a control shelf **506** for carrying maintenance and administration processor cards, and extension shelves **508** and **510** for carrying link interface and database service modules. Frame **512** includes three extenion sheves **514**, **516**, and **518**, also for carrying link interface and database service modules. In the illustrated example, each shelf in frames **504** and **512** includes a network monitoring transport card **104**.

Distributing network monitoring transport cards **104** in this manner is preferred for reliability reasons because this distribution prevents a total network monitoring failure in the event that an entire shelf or frame loses power. However, the present invention is not limited to distributing network monitoring transport cards **104** across multiple shelves in multiple frames. In an alternate (but less preferred) embodiment, network monitoring transport cards **104** may be located in the same rack in the same frame.

The number of network monitoring transport cards included in a routing node depends on the number of links serviced by the routing node. In one example, there may be one network monitoring transport card per 64 signaling links plus additional network monitoring transport cards in an n+m redundancy scheme. For instance, if there are 128 links in a routing node, n=2 network monitoring processor cards may service these links. In addition, there may be m=1 redundant network monitoring transport cards in case one of the primary network monitoring transport cards fails.

System Software and Automatic Configuration Methods

As stated above, one of the primary advantages of a network monitoring system according to the present invention is the ability to automatically configure itself when the link configuration of a network routing node being monitored changes. Figure 6 is a protocol layer and software block diagram illustrating exemplary protocol layers and software associated with an automatically configurable network monitoring system according to an embodiment of the present invention. In Figure 6, LIM **102** and network monitoring processor **106** each include a layered communication protocol stack for communicating network monitoring messages. In the illustrated example, the communication protocol stacks each include a physical layer (represented by “Media” in Figure 6) for sending and receiving bits over a physical medium, a link layer **602** for ensuring reliable point to point connections, a network layer **604** for datagram routing and delivery and a transport layer **606** for transporting messages over the underlying network. Layers **602**, **604**, and **606** may be implemented using a standard communication protocol stack, such as TCP/IP or UDP/IP over Ethernet.

According to an important aspect of the invention, each protocol stack also includes a *network monitoring communications protocol* layer **608** for establishing and maintaining network monitoring sessions between LIMs **102** and network monitoring processor **106**. On the side of LIM **102**, network monitoring communications protocol layer **608** includes a network monitoring client **610**. On the side of network monitoring processor **106**, network monitoring communications protocol layer **608** includes a provisioning manager **612** that functions as a network monitoring server. Network monitoring client **610** and provisioning manager **612** exchange network management protocol messages, which will be discussed in detail below, to establish and maintain network monitoring sessions and to communicate network monitoring messages over the sessions.

Application layers **614** associated with the communication protocol stacks each include one or more applications that use the services provided by network monitoring communications protocol layer **608** to perform network monitoring functions. In the illustrated example, application layer **614** of LIM **102** includes a signaling message copier **616** for copying signaling messages sent over a signaling link being monitored and an alarm/event generator **618** for generating alarms and events relating to the operation of the signaling link or routing node being monitored.

Application layer **614** of network monitoring processor **106** includes alarm handlers **620** for receiving alarms generated by alarm/event generator **618** and application handlers **622** for receiving signaling message copies copied by signaling message copier **616**. Provisioning manager **612** may select an application handler **622** or an alarm handler **620** in response to a received service request based on signaling links that are pre-assigned to a particular application handler or alarm handler, in the manner discussed above.

Figure 7 is a flow chart illustrating exemplary overall steps for automatically configuring a network monitoring system according to an embodiment of the present invention. Referring to Figure 7, in step **ST1**, a link interface module boots up and brings a signaling link into service. In step **ST2**, the network monitoring client associated with the link interface module broadcasts a service request message to a well known UDP port on which the network monitoring processor software is listening. In step **ST3**, the network monitoring processors receive the service request. In step **ST4**, software on each network monitoring processor determines if it is provisioned to handle the signaling link identified in the service request. If the network monitoring processor software determines that it is not provisioned to handle the service request, in step **ST5**, the network monitoring processor software discards the service request. In step **ST6**, if the network monitoring processor software determines that it is provisioned to handle the service request, the network monitoring processor software accepts the request. In step **ST7**, the network monitoring processor software establishes a network monitoring session with the requesting client.

Once a session is established, signaling messages or alarms, depending on the session type are sent from the link interface module to the network monitoring processor software via for example a TCP/IP connection (step **ST8**). The network monitoring transport cards forward messages received from the link interface modules to the network monitoring processors. The TCP/IP messages used to carry the network monitoring messages are addressed to the network monitoring processor software associated with the link being monitored.

According to another important aspect of the invention, the network monitoring processor and the link interface module being monitored preferably exchange heartbeat or keepalive messages at predetermined time intervals to maintain a network monitoring session. If the network monitoring processor determines that a heartbeat message has not been received within a predetermined time period, the network monitoring session is terminated (step **ST9**) and network monitoring resources on the network monitoring processor are freed (step **ST10**). Using this heartbeat mechanism, the present invention automatically detects when a link is taken out of service and reconfigures itself so that network monitoring resources are no longer dedicated to the out of service link.

Network Monitoring Messaging

According to yet another aspect of the invention, the network monitoring communications protocol includes a set of messages for establishing network monitoring sessions, exchanging information during the sessions, and changing one or more aspects of the sessions. Table 1 shown below illustrates exemplary network monitoring session messages that may be used for communications between a network monitoring client and a network monitoring server according to an embodiment of the present invention.

Network Monitoring Message	Usage
Heartbeat	Periodic message transmitted bi-directionally to ensure connectivity between applications.
Service Request	A network monitoring client service request that includes the requestor's provisioning information.
Service Accept	A network monitoring server service acceptance response to the received service request that includes provisioning information from the grantor.
Service Reject	A network monitoring server service rejection response to the received service request, which includes the reason for rejection.
Provisioning Info	An informational message sent to the application connection that contains provisioning data.
Event	Network monitoring client transmission of events/alarms.
Link Data	Network monitoring client transmission of link data (MSUs).
Service Change	An indication that the network monitoring server wishes to change service modes (i.e., alter transmission mode of MSUs and/or events).

Table 1: Network Monitoring Messages

In Table 1, the network monitoring messages include heartbeat, service request, service accept, service reject, provisioning information, event, link data, and service change. The heartbeat message is transmitted periodically by each side of a network monitoring session to maintain connectivity. The service request messages are used by network monitoring clients to request network monitoring service. The service accept and reject messages are used by the network monitoring servers to accept or reject service requests. The provisioning information message is sent from a network monitoring client to an application connection to deliver provisioning information to the application connection. The event message is sent from the network monitoring client to the network monitoring server to deliver event information to the network monitoring server. The link data message is used by the network monitoring client to deliver link data, such as a copied MSU, to the network monitoring server. The service change message is used by the network monitoring server to change the type of network monitoring service being provided.

Figure 8 is a message flow diagram illustrating exemplary messages that may be exchanged by network monitoring client **610** residing on a link interface module and software executing on network monitoring processor **106** in establishing and maintaining a system alarm session. Referring to Figure 8, in line 1, network monitoring client **610** sends a network monitoring service request message to network monitoring processor **106**. The network monitoring service request message includes an indicator that it requests system alarm service. The network monitoring service request message is preferably broadcast to a predetermined UDP port monitored by network monitoring processor **106**.

Network monitoring processor **106** receives the network monitoring service request message. Provisioning manager **612** identifies the message as requesting alarm service and selects one or more alarm handlers **620** assigned to handle the service request. Provisioning manager **612** formulates a network monitoring accept message and, for each alarm handler assigned to process the request, sends a network monitoring service accept message. The network monitoring service request message includes for example the TCP port and IP address of the alarm handler configured to provide the requested service.

In line 3, network monitoring client **610** establishes a TCP connection with an alarm handler **620** residing at the TCP/IP address received in the service accept message and sends a provisioning information message to this address. The provisioning information message may also include provisioning information about the routing node being monitored, such as the number and type of links provided by the routing node. Once the provisioning information message is sent, an alarm session is established between alarm handler **620** and network monitoring client **610**.

In lines 4 and 5, alarm handler **620** and network monitoring client **610** exchange heartbeat messages. The heartbeat messages are sent periodically to maintain the alarm session. In lines 6 and 7, network monitoring client **610** sends event messages communicating the raising and clearing of a system alarm associated with the routing node being monitored. This information may be passed to an alarm server so that the operator can take appropriate action.

In line 8, another alarm handler accepts the original service request by sending a service accept message. The network monitoring service accept message includes the new TCP port and IP address of the new alarm handler **620**. In line 9, network monitoring client **610** establishes a TCP connection with the new alarm handler **620** sends a provisioning information message to the new alarm handler **620**. The provisioning information message may include provisioning information about the routing node being monitored, such as the number and type of links provided by the routing node.

In lines 10 and 11, the new alarm handler **620** and network monitoring client **610** exchange heartbeat messages. In lines 12-15, network monitoring client **610** sends event messages communicating the raising and clearing of system alarms associated with the routing node being monitored. This information may be passed to an alarm server so that the operator can take appropriate action.

In lines 16 and 17, provisioning manager **612** and network monitoring client **610** exchange heartbeat messages to ensure that both ends of the connection are still alive. If network monitoring client **610** fails to send a heartbeat message within a predetermined time period, network monitoring processor **106** assumes that the link is down or removed and frees link monitoring resources associated with the downed link.

Figure 9 illustrates exemplary messages that may be exchanged between network monitoring client **610** and network monitoring processor **106** in establishing a link data session and communicating over the link data session. In line 1, network monitoring client **610** broadcasts a network monitoring service request to the well known UDP port on which provisioning manager **612** of network monitoring processor **106** is listening. In line 2, the provisioning manager returns the TCP address and port number of the application handler **620** assigned to provide network monitoring service for the particular link identified in the service request. Application handlers **620** are preferably preconfigured to provide network monitoring service to a predetermined set of wired and equipped signaling links in a network routing node. If a new link comes in service and request network monitoring service, an application handler **620** will be able to automatically start serving the new signaling link.

In line 3, network monitoring client **610** obtains the address of application handler **620** from the service accept message, establishes a TCP/IP connection with application handler **620** at that address, and formulates and sends a provisioning information message to application handler **620**. The provisioning information message includes provisioning information regarding the routing node being monitored. After sending the provisioning information message, in lines 4-6, network monitoring client **610** sends link data messages, including copied MSUs or other types of signaling messages, to application handler **620**. Application handler **620** receives and buffers the MSUs. In lines 7 and 8 network monitoring client **610** and network monitoring processor **106** exchange heartbeat messages to maintain the link data session.

In lines 9 and 10, network monitoring client **610** communicates link alarm data to application handler **620**. In lines 11 and 12, network monitoring client **610** communicates additional link data to application handler **620**. In lines 13 and 14, provisioning manager **612** and network monitoring client **610** exchange heartbeat messages to maintain the session.

When a user, such as a fraud or billing application, desires to stop the flow of signaling data to network monitoring processor **106**, the user informs application handler **620**. In response, application handler **620** sends a service change message requesting that network monitoring client **610** cease the flow of MSUs to network monitoring processor **106** (line 15). In response, network monitoring client **610** ceases sending MSU copies over the TCP/IP connection. However, the network monitoring connection is maintained via the periodic exchange of heartbeat messages (lines 16 and 17). In line 18, when the user determines to continue the flow of MSUs, application handler **620** sends a service change message requesting the MSU flow be continued. In response, network monitoring client **610** resumes sending link data (lines 19 and 20). Thus, through the exchange of a defined sequence of messages, a user can automatically maintain and control a network monitoring connection.

Timing

Network monitoring client **610**, provisioning manager **612**, and handlers **620** and **622** use timers to determine the next action to take. Table 2 shown below illustrates exemplary timers that may be maintained by network monitoring client **610**, provisioning manager **612**, and handlers **620** and **622**.

Timer	Usage	Duration	Start	Stop	On Expiry
T-501	Heartbeat transmission timer.	1 second	After transmission of a Heartbeat message	Session termination.	Transmit Heartbeat message.
T-503	Lost heartbeat timer.	2 seconds	After reception of peer Heartbeat message (**reset operation**).	After reception of peer Heartbeat message (**reset operation**).	Stop all timers. Terminate.
T-505	Service Response timer.	Range: 15 seconds to 60 seconds	After transmitting Service Request message.	After receiving all due responses (Service Accept/ Reject messages).	Retransmit Service Request message.

Table 2: Network Monitoring Communication Protocol Timers

In Table 2, timers T-501 – T-505 are maintained by each side of a network monitoring connection and each controls certain actions to be performed. For example, T-501 is the heartbeat transmission timer. Its duration is one second. T-501 starts after transmission of a heartbeat message and ends if the session terminates before the timer expires. If T-501 expires, a heartbeat message is transmitted. Thus, the timer T-501 causes each side of a network monitoring connection to transmit a heartbeat message every second.

Timer T-503 is used to detect lost heartbeat messages. For example, if one side of a network monitoring session receives a heartbeat message, it should receive another heartbeat message in about one second, since each side transmits a heartbeat message every second. If there is no heartbeat message received from the other side in two seconds, it is assumed that the heartbeat message is lost or the other link is out of service. In this situation, the network monitoring session is terminated.

T-505 is a retransmission timer for network monitoring service request messages. Since service request messages are broadcast over UDP, which provides unreliable datagram services, it is possible that the service request message may not reach one or more of its intended destinations. T-505 starts when a service request message is transmitted. If all due responses to the service request messages are not received within the timeout period, the service request message is retransmitted.

Network Monitoring Communication Protocol State Machines

Network monitoring client **610**, provisioning manager **612**, and application handler **622** may each implement a state machine that defines the overall operation of these entities. Figures 10A, 10B, and 10C illustrate exemplary state machines that may be associated with network monitoring client **610**, provisioning manager **612**, and application handler **622**, respectively. Referring to Figure 10A, network monitoring client state machine **1000** includes a network monitoring closed state **1002**, a network monitoring connected stated **1004**, a network monitoring connection pending state **1006**, a TCP connection pending state **1008**, and a network management service request pending state **1010**. The lines interconnecting the states represent state transitions. The text written on the lines indicates the actions that cause the state transitions.

Network monitoring client **610** begins in network monitoring session closed state **1002**. Network monitoring client then issues a network monitoring service request, which results in a transition to network monitoring service request pending state **1010**. In this state, if the service request retransmission timer times out, the service request is retransmitted, and network monitoring client **610** remains in this state. Similarly, if network monitoring client **610** receives a service reject message, network monitoring client **610** retransmits the service request and remains in state **1010**. Receipt of a network monitoring service accept message causes network monitoring client **610** to transition to TCP connection pending state **1008**.

In TCP connection pending state **1008**, network monitoring client **610** sends a TCP connection request to the address received in the network monitoring service accept message. When the TCP connection is established, network monitoring client **610** transitions to the network monitoring connection pending state **1006**. This state is a transitory state. Network monitoring client **610** remains in network monitoring connection pending state only until network monitoring client **610** transmits a provisioning information message to network monitoring application handler **622**. Once this message is sent, network monitoring client **610** transitions to network monitoring connected state **1004**. In state **1004**, network monitoring client may send events and MSUs to network monitoring application handler **622**. Network monitoring client **610** also transmits heartbeat messages to network monitoring application handler **622**. If a lost heartbeat timeout occurs, network monitoring client **610** returns to network monitoring session closed state **1002**.

Referring to Figure 10B, provisioning manager state machine **1012** includes a start state **1014**, an active state **1016**, and a lockout state **1018**. Provisioning manager **612** begins its operation in start state **1014**. In this state, provisioning manager **612** activates itself and transitions to active state **1016**. In active state **1016**, provisioning manager **612** receives network management service request messages and either accepts or rejects the requests. If provisioning manager **612** receives an inhibit command from a user, provisioning manager **612** transitions to lockout state **612** where provisioning manager **612** remains until a release or timeout occurs.

Referring to Figure 10C, application handler state machine **1020** includes a network monitoring session closed state **1022**, a network monitoring connected state **1024**, a network monitoring connection pending state **1026**, and a TCP connection pending state **1028**. Application handler **622** begins its operation in network monitoring session closed state **1022** and remains in this state until it receives an application request from provisioning manager **612**. In response to receipt of the activation request, application handler **622** transitions to TCP connection pending state **1028**. In TCP connection pending state **1028**, application handler **622** waits for a TCP connection request from network monitoring client **610** and establishes a TCP connection in response to the request.

Once a TCP connection is established, application handler **622** transitions to network monitoring connection pending state **1026**. In network monitoring connection pending state **1026**, application handler **622** transmits heartbeat messages to network monitoring client **610** and receives heartbeat messages from network monitoring client **610**. If a heartbeat is lost, application handler **622** returns to network monitoring connection closed state **1022**. If application handler **622** receives provisioning information, application handler **622** transitions to network monitoring connected state **1024**. In state **1024**, application handler **622** receives MSUs, events, and heartbeats from network monitoring client **610**. Application handler **622** also transmits heartbeats and service change requests to network monitoring client **610** in state **1024**. Application handler **622** remains in state **1024** until the heartbeat from network monitoring client **610** is lost. In this case, network monitoring client **610** returns to network monitoring connection closed state **1022**. Thus, as illustrated in Figures 10A-10C, the present invention implements state machines for automatically establishing, maintaining, and reconfiguring network monitoring connections.

Network Monitoring Message Formats

According to yet another aspect, the present invention includes message formats recognizable by network monitoring client **610**, provisioning manager **612**, alarm handlers **620**, and application handlers **622** for performing network monitoring functions. Figure 11 illustrates an exemplary network monitoring message format suitable for use by embodiments of the present invention. In Figure 11, a network monitoring message **1100** includes a header portion **1102** and a data portion **1104**. Header portion **1102** includes a mandatory preamble that identifies the message as a network monitoring message. In the illustrated example, the preamble includes the characters "ESFS". The header also includes a message type field for storing the message type and a message length field for storing the length of the message. Table 3 set forth below illustrates exemplary values that may be used to identify the various network monitoring message types:

Message	Coding	Indication
Heartbeat	0x01	Periodic message transmitted to ensure connectivity.
Service Request	0x02	Service request from the routing node being monitored.
Service Accept	0x82	Service response from the network monitoring processor indicating acceptance of service request.
Service Reject	0xC2	Service response from the network monitoring processor indicating rejection of service request.
Provisioning Info	0x04	Connectivity message to application handler connection, which includes provisioning information, from the routing node being monitored.
Event	0x05	Event/Alarm indication from the routing node being monitored.
Link Data	0x06	Link data (MSUs) indication from the routing node being monitored.
Service Change	0x07	Network monitoring processor request to change service mode (i.e., alter transmission mode of MSUs and/or events).

Table 3: Network Monitoring Message Type Codes

In Table 3, the leftmost column contains the names of the network monitoring messages used to implement the present invention. The next column stores the hexadecimal code stored in the message type field of the network managment messasge header illustrated in Fgure 11. The final column in Table 3 includes a short deceription of the function of each message type.

Figure 12 illustrates an exemplary heartbeat message format suitable for use by embodiments of the present invention. In Figure 12, heartbeat message **1200** includes a header **1102** and a data portion **1104**. The header portion of heartbeat message **1200** includes the heartbeat message type code (0x01). The data portion of heartbeat message **1200** contains all zeros. The heartbeat message is not required to carry any data because its use is simply to verify that the remote end of a connection is still functioning.

Figure 13 illustrates an exemplary network monitoring service request message format suitable for use by embodiments of the present invention. In Figure 13, network monitoring service request message **1300** includes a header portion **1102** and a data portion **1104**. Header portion **1102** identifies the message as a network monitoring service request message. Data portion **1104** includes a plurality of fields associated with requesting network monitoring service. Each of these fields will now be described in detail.

The data portion of a service request message begins with the eighth octet. The eighth and ninth octets in service request message **1300** contains the network monitoring communication protocol version number, which is used to establish compatibility between network monitoring client **610** and alarm and application handlers **620** and **622** associated with network monitoring processor **106**. The network monitoring communications protocol version octets field contains a value indicating the version of the network monitoring communications protocol being used by the entity that sent the network monitoring service request message.

Octets ten and eleven in service request message **1300** contain the card ID. The card ID is used to identify a particular card or printed circuit board in the routing node being monitored. In one example, the card ID field may be a two-octet field indicating the slot location (e.g., 1101, 1207, 2205, etc.) of the card.

Octet twelve in service request message **1300** contains the card port ID of the card that sent the service request message. The card port ID identifies the port requesting service on the card.

Octet thirteen in service request message **1300** contains the service type. The service type identifies the type of service being requested. Table 4 shown below illustrates exemplary service types that may be stored in the service type field.

Coding	Indication
0x01	LINK DATA reporting
0x02	SYSTEM ALARM reporting

Table 4: Service Types and Type Codes

Octet fourteen in service request message **1300** contains the transaction ID. The transaction ID identifies a particular request. As service request messages may be retransmitted, this field provides the means of identifying which request is being processed. The transaction ID field of the initial service request message may be coded to one (1). The transaction ID field may be incremented when the contents of the service request message change.

Octet fifteen in service request message **1300** contains the link type. The link type is used to indicate the type of SS7 link that is being provisioned. Table 5 shown below illustrates exemplary values that may be included in the link type field to encode various SS7 link types.

Coding	Indication
0x41 ('A')	A (Access) link
0x42 ('B')	B (Bridge) link
0x43 ('C')	C (Cross) link
0x44 ('D')	D (Diagonal) link
0x45 ('E')	E (Extended) link
0x46 ('F')	F (Fully associated) link

Table 5: Link Type Values

Octet sixteen in service request message **1300** contains the link interface. The link interface is used to indicate the physical interface for the SS7 link for which network monitoring service is being requested. Table 6 shown below illustrates exemplary values that may be included in the link type field to encode various physical link types.

Coding	Indication
0x01	DS0A – 56K
0x02	DS0A – 64K
0x03	V.35 – 56K
0x04	V.35 – 64K
0x05	OCU – 56K
0x06	OCU – 64K
0x07	E1/T1 – 56k
0x08	E1/T1 – 64k

Table 6: Physical Interface Type Codes

Octets seventeen through twenty in service request message **1300** contain the near end point code (NEPC) assigned for the SS7 link for which network monitoring service is being requested. Table 7 shown below illustrated exemplary point code encoding for the most significant byte of the NEPC field.

Coding	Indication
0x00	ANSI National FULL Point Code Routing
0x01	ITU International Point Code Routing
0x02	ITU National Point Code Routing
0x03	ANSI Network Point Code Routing
0x04	ANSI Simple Network Cluster Addresses
0x05	ANSI All Network Cluster Addresses
0x06	ANSI All Full Point Code and Network Cluster Address
0x07	ANSI All Addresses of a Network Cluster
0x08	ANSI All Addresses of a Network Cluster and Network Cluster Addresses

Table 7: Point Code Type Octet Coding

Octets twenty-one through twenty-four in service request message **1300** contain the far end point code (FEPC). The FEPC is used to indicate the far end point code assigned for the SS7 link for which SS7 network monitoring service is being requested. The MSB octet contains an indication of the point code standard, as defined in Table 7.

Octet twenty-five in service request message **1300** contains the signaling standard. This field is used to indicate the signaling standard assigned to the SS7 link for which network service is being requested. The signaling standard contains a value as defined in Table 8 shown below.

Coding	Indication
0x01	ANSI
0x02	ITU International
0x03	ITU National

Table 8: Signaling Standard Codes

Octet twenty-six in a service request **1300** message contains the linkset name string length. The octets following the linkset name string length field in service request message **1300** contain the linkset name string. The linkset name string octets contain a string representing the link's assigned name (e.g., "Boston187").

The octet following the linkset name string in service request message **1300** contains the CLLI string length. The octets following the CLLI string length in the Service Request message contains the CLLI string. The CLLI string octets contain a string representing the assigned CLLI (e.g., "RLGHNCXA03W").

Figure 14 illustrates an exemplary service accept message format suitable for use by embodiments of the present invention. In Figure 14, service accept message **1400** includes a header portion **1102** and a data portion **1104**. Header portion **1102** includes a message type code (0x82) for identifying the message as a service accept message. Data portion **1104** includes various fields relating to service acceptance, which will now be described in detail.

The first octet after header portion **1102** in the service accept message is octet eight. The eighth and ninth octets in service accept message **1400** contain a network monitoring communication protocol version number. The version number is used to establish compatibility between network monitoring client **610** and network monitoring communication protocol software executing on network monitoring processor **610**.

Octet ten in service accept message **1400** contains the service mode. The service mode is used to indicate the type of service granted by network monitoring processor **106**. The service mode octet contains one of the values defined in Table 9 shown below to indicate the service mode.

Coding	Indication
0x01	Copy Rx MSUs Only
0x02	Copy Tx MSUs Only
0x03	Copy All MSUs
0x04	Alarm Service Only
0x05	Alarm Service and Copy Rx MSUs
0x06	Alarm Service and Copy Tx MSUs
0x07	Alarm Service and Copy All MSUs

Table 9: Service Mode

The codes in Table 9 indicate the type of service that network monitoring processor **106** accepts. For example, if network monitoring processor **106** returns a service mode of 0x06 to network monitoring client **610** in the service accept message, this indicates to network monitoring client **610** that network monitoring processor **106** has accepted service for copies of received message signal units only. In response to such a service acceptance, network monitoring client **610** can begin send copies of received MSUs to the network monitoring processor **106** that accepted the service request.

Octet eleven in service accept message **1400** contains the transaction ID. The Transaction ID is used to correlate service request messages service responses. For example, in order to accept a particular service request, network monitoring processor **106** copies the transaction ID value from the corresponding field in the service request message. When network monitoring client **610** receives the service accept message, network monitoring client **610** uses the transaction ID field to match the service acceptance message with a pending service request.

Octet twelve in service accept message **1400** contains a value indicating the number of responses. The number of responses value inform the network monitoring client **610** of the number of service responses that will be transmitted in response to a particular service request. For instance, in the case of alarm service request, there may be multiple entities responding to the service request.

Octets thirteen through sixteen in service accept message **1400** contain the IP Address of the entity accepting the service request. The entity may be an application handler **622** or an alarm handler **620**. Network monitoring client **610** uses this IP address to establish a network monitoring connection with the grantor. As described above, the service request message is broadcast to all application processors **106**. However, only the application processor(s) provisioned to provide service for a particular link agree to provide service for that link. The IP address is used by network monitoring client **610** to receive service from the granting entity.

Octets seventeen and eighteen in the service accept message **1400** contain the TCP port number of the entity on application processors **610** that accepts a particular service request. For example, service may be accepted by a particular application handler **622** or a particular alarm handler **620**. Each of these entities comprises software listening on a predetermined TCP port. This

TCP port number is returned in the service accept message so that network monitoring client **610** can initiate a network monitoring connection with the service providing entity at the specified TCP port.

Figure 15 illustrates an exemplary service reject message format suitable for use by embodiments of the present invention. In Figure 15, service reject message includes a header portion **1102** and a data portion **1104.** Header portion **1102** includes a value (0xC2) used to identify the message as a service reject message. Data portion **1104** of service reject message **1500** includes various fields associated with service rejection, which will now be explained in detail.

Octet 8 is the first octet in data portion **1104** of service reject message **1500.** The eighth and ninth octets in service reject message **1500** contain the network monitoring protocol version number. As stated above, the version number is used by software executing on the routing node being monitored and software on network monitoring processor **106** to identify the network monitoring communications protocol version being used.

Octet ten in service reject message **1500** contains a service mode value (0x00) indicating that no service is being granted. Thus, unlike the service accept message, which contains a value indicating a type of service being granted, service reject message **1500** includes a service type value indicating that no service is being granted.

Octet eleven in service reject message **1500** contains a transaction identifier. As stated above, the transaction identifier is used by network monitoring client **610** and network monitoring communication protocol software executing on processor **106** to match messages belonging to the same transaction. For example, to reject a particular service request, provisioning manager **612** executing on network monitoring processor **106** preferably copies the transaction ID from a received service request message into the corresponding field of a service reject message to be sent to the requesting entity.

Octet twelve in service reject message **1500** contains the number of responses that will be sent in response to a particular service request. Network monitoring client **610** uses this value to determine whether all responses have been received in response to a service request. If all responses have not been received within a predetermined timeout period as described above, network monitoring client **610** may re-issue the service request.

Octets thirteen in service reject message **1500** contains a value indicating the reason that network monitoring processor **106** rejected the particular service request. Table 10 shown below indicates various reasons and corresponding codes that may be used in a service reject message.

Coding	Indication
0x01	Bad NMCP Version
0x02	No Resources Available
0x03	Administratively Disabled
0x04	Invalid Message Coding

Table 10: Service Rejection Reason Codes

From Table 10, one reason for rejecting a service request is when the service request message contains a network monitoring communication protocol version that is either invalid or incompatible with the version being run on the network monitoring processor answering the service request. Another reason for rejecting the service request is when network monitoring processor **106** lacks resources to provide the requested network monitoring service. Additional reasons for rejecting a service request that may be included in service reject message **1500** are invalid coding of the service request message and administrative disablement of the service providing functions.

Octet fourteen in service reject message **1500** contains the reason string length. The reason string length octet contains a value indicating the length of a variable length reason text string providing further information as to why service is rejected. The octets following the reason string length in service reject message **1500** contain a text string representing the reason that the service request has been rejected (e.g., "Invalid coding of service mode field").

Figure 16 illustrates an example of a provisioning information message format suitable for use by embodiments of the present invention. As discussed above, network monitoring client **610** the provisioning info message to provide the provisioned SS7 link data to provisioning manager **612**. As illustrated in Figure 16, provisioning info message **1600** includes a header portion **1102** and a data portion **1104**. Header portion **1102** includes a value (0x04) identifying the message as a provisioning information message. Data portion **1104** includes various fields carrying the link provisioning information of the node being monitored. Each of the octets in data portion **1104** of provisioning info message will now be explained in further detail.

The eighth and ninth octets in provisioning info message **1600** contain the network monitoring communication protocol version number. As discussed above, the network monitoring communication protocol version number is used to establish compatibility between network monitoring communication protocol software executing on the routing node being monitored and on network monitoring processor **106**

Octets ten and eleven in provisioning info message **1600** contain an identifier for the card slot of the card in the routing node corresponding to the link being monitored. Octet twelve in provisioning info message **1600** contains a value that identifies the particular port requesting service in the routing node being monitored.

Octet thirteen in provisioning info message **1600** contains a value that indicates the type of service granted by network monitoring processor **106.** Table 4 illustrated above includes exemplary service type codes that may be stored in octet 13 of provisioning info message **1600**.

Octet fourteen in the provisioning info message **1600** is stores a value indicating a particular service request. Network monitoring client **610** preferably includes the same value in octet 14 of provisioning info message **1600** that was included in the corresponding field of the service accept message. Network monitoring communication protocol software executing on network monitoring processor **106** uses the transaction ID in the provisioning info message to match the provisioning info message with a particular service acceptance.

Octet fifteen in provisioning info message **1600** contains the link type. The link type is used to indicate the type of SS7 link being monitored. Exemplary encodings for the link type octet are shown above in Table 5.

Octet sixteen in provisioning info message **1600** contains the physical link interface type. Table 7 shown above illustrates exemplary encodings for the physical link interface type.

Octets seventeen through twenty in provisioning info message **1600** contain the near end point code. As discussed above with respect to the service request message, the near end point code is a value that indicates the point code terminated by the signaling link being monitored. Octets twenty-one through twenty-four in provisioning info message **1600** contain the far end point code. As discussed above with respect to the service request message, the far end point code is the point code at the far end of the signaling link being monitored.

Octet 25 in provisioning info message **1600** contains the signaling standard. Exemplary signaling standards and their corresponding codes are illustrated above in Table 8.

Octet twenty-six in provisioning info message **1600** contains the linkset name string length. The linkset name string length indicated the length in octets of the linkset name that follows. The octets following the linkset name string length field in provisioning info message **1600** contain the linkset name string. As discussed above with respect to the service request message, the linkset name string octets contain a string representing the link's assigned name (e.g., "Boston187").

The octet following the linkset name string in provisioning info message contains the CLLI string length indicating the length of the CLLI string field that follows. The octets following the CLLI string length in provisioning info message **1600** contain the CLLI string. The CLLI string octets contain a string representing the assigned CLLI (e.g., "RLGHNCXA03W").

The event message is used to carry event information from network monitoring client **610** to network monitoring processor **106**. Figure 17 illustrates an event message suitable for use by embodiments of the present invention. In Figure 17, event message **1700** includes a header portion **1102** and a data portion **1104**. Header portion **1102** preferably includes a value (0x05) for identifying the message as an event message. Data portion **1104** includes various fields for communicating event information to network monitoring processor **106**. These fields will now be discussed in more detail. Octets eight and nine in event message **1700** contain the card ID. The card ID identifies a particular card in the routing node being monitored from which the event message originated. In one example, the card ID may store the slot location of the card associated with the event.

Octet ten in event message **1700** contains the card port ID. The card port ID identifies the port on the routing node being monitored that witnessed the reported event.

Octets eleven through eighteen in event message **1700** contain a timestamp. The timestamp represents the time that the event being reported occurred. The timestamp may be in any suitable format, such as the Unix timespec format of thirty-two (32) bits for seconds since January 1st, 1900 and thirty-two (32) bits for nanoseconds.

Octet nineteen in event message **1700** contains an event code for the event being reported. Table 11 shown below illustrated exemplary events and corresponding codes that may be included in the event code field.

Code	Indication	Description
0x10	NMTC Card Unavailable	NMTC card is out of service
0x11	NMTC Card Available	NMTC card is in service
0x12	NMTC Network Unavailable	The Network connected to the DCM (port A/B) is inaccessible.
0x13	NMTC Network Available	The Network connected to the DCM (port A/B) is accessible.
0x14	ALL NMTC Networks Unavailable	If all the connections off the DCM cards are inaccessible (port A and B)

Code	Indication	Description
0x15	ALL NMTC Cards Unavailable	If all the DCM cards are inaccessible
0x16	EROUTE is Removed	All NMTC cards have been deleted.
0x17	EROUTE System is Available	The EROUTE system is granting at a rate that does not exceed the threshold (80% of 1700 * N EROUTE cards).
0x18	EROUTE System Threshold Exceeded	The EROUTE system has reached a granting rate higher than its threshold.
0x19	EROUTE System Capacity Exceeded	The EROUTE system has reached a granting rate higher than its capacity (1700 grants per sec * N EROUTE cards).
0x1A	EROUTE capacity normal, card(s) abnormal	The EROUTE system is granting at a rate that does not exceed the threshold (80% of 1700 * N EROUTE cards). However, one or more cards are OOS-MT.
0x1B	NTP Time Unavailable	The NTP time is unavailable
0x1C	NTP Time Available	The NTP time is available
0x1D	Congestion: Copy Function De-activated	The Copy Function on the SS7 cards has been de-activated.
0x1E	Copy Function Activated	The Copy Function on the SS7 cards has been activated.
0x1F	Link not Monitored	This is a possible clearing condition for Congestion: Copy Function Deactivated. This implies that the NMP is not monitoring this Link any longer so any Monitoring alarms should be cleared.
0x20	Timestamp Invalid	LIM card's timestamp is invalid
0x21	Timestamp Valid	LIM card's timestamp is valid
0x30	SS7 Card Unavailable	SS7 link card is out-of-service.
0x31	SS7 Card Available	SS7 link card is in-service.
0x32	Clock A Failed	Routing node Clock A Failed
0x33	Clock A Normal	Routing node Clock A Normal
0x34	Clock B Failed	Routing node Clock B Failed
0x35	Clock B Normal	Routing node Clock A Normal
0x36	Clocks A and B Failed	Routing nodeClocks A and B failed
0x37	Clocks A and B Normal	Routing node Clocks A and B Normal
0x38	LIM has been denied SCCP Service	The LIM cannot get service from an SCCP card

Code	Indication	Description
0x39	LIM has been denied NM Service	The LIM cannot get service from NMP
0x3A	SS7 Link Available	Possible Clearing Condition for the following link alarms (0x3A to 0x61) (level = MAJOR).
0x3B	Alarm cleared by deleting SLK	Possible Clearing Condition for the following link alarms (0x3A to 0x62) (level = MAJOR).
0x3C	Too Many Interrupts	Indicates the link has had numerous interruptions
0x3D	Lost Data	Signaling link has lost data
0x3E	SUERM Threshold Exceeded	The signal unit error rate monitor (SUERM) has exceeded the threshold because there are too many alarms.
0x3F	Lvl-2 T1 Expd (ready)	The signaling link did not receive a fill-in or message signal unit after the proving period.
0x40	Lvl-2 T1 Expd (not ready)	The signaling link did not receive a fill-in or message signal unit after the proving period.
0x41	Lvl-2 T3 Expired	The link did not receive an SIN or an SIE before the T3 timer expired
0x42	Lvl-2 T2 Expired	The link did not receive an SIN, SIE or SIOS
0x43	Failed Proving Period	The signaling link has failed the proving period
0x44	OSA – Received SIO	The signaling terminal has received the status indication Out of Alignment from the far end
0x45	OSA – Received SIN	The signaling terminal has received the status indication normal proving from the far end
0x46	OSA – Received SIE	The signaling terminal has received the status indication emergency alignment from the far end
0x47	OSA – Received SIOS	The signaling terminal has received the status indication Out of service from the far end
0x48	ABN – rcvd 2 of 3 invalid BSN	The link has received 2 out of 3 invalid backward sequence numbers (BSNs) from the far end.
0x49	ABN – rcvd 2 of 3 invalid FIB	The link has received 2 out of 3 invalid forward indicator bits (FIB) from the far end.

Code	Indication	Description
0x4A	Remote congestion Timeout	The remote node has been in congestion too long. The T6 timer has timed out.
0x4B	XDA – Excess acknowledge delay	The far end is taking too long to acknowledge the messages sent to it by the signaling terminal. The T7 timer has timed out.
0x4C	COO – rcvd changeover order	The signaling link has received a changeover order from the far end.
0x4D	False congestion restart	This message indicates the signaling link has entered a congested state even though the traffic on the linkset is not high enough to cause congestion.
0x4E	MTP link restart delayed	Indicates that a link has gone in and out of service.
0x4F	Remote FE Loopback	This message indicates that the specified link has been looped back from the far end.
0x50	Link Test Failed	Link Test Failed
0x51	Remote Blocked	The link is blocked due to an event at the far end
0x52	Local Blocked	The local technician has put the signaling link in processor outage.
0x53	Remote Inhibited	A craft person at the far end has remotely inhibited the link.
0x54	Local Inhibited	The link has been inhibited locally
0x55	Not Aligned	The link has lost alignment. It can not longer carry traffic.
0x56	LM Timer NO-CREDIT Expired	The remote node has held the local node in a no-credit state for too long.
0x57	XDA- Timer NO-RESPONSE expired	The far end is not responding to the outgoing POLL messages.
0x58	Local Processor Outage	Indicates a spontaneous or management initiated processor outage.
0x59	Rcvd SSCOP END – proc outage	The far end sent an "END processor outage" protocol data unit (PDU).
0x5A	Rcvd SSCOP END – out of service	The far end sent an "END out of service" protocol data unit (PDU).
0x5B	Rcvd SSCOP END – protocol error	A protocol error has occurred on the far end.
0x5C	Rcvd SSCOP END – mcmnt initiated	The MAAL layer (not a user) on the far end released a link.

Code	Indication	Description
0x5D	FAC – DS1 LOS failure	The level 1 facility outage: loss of signal
0x5E	FAC – DS1 LOF failure	The level 1 facility outage: loss of frame
0x5F	FAC – DS1 LCD failure	The level 1 facility outage: loss of cell delineation.
0x60	XER – ISERM Threshold Exceeded	The in service error rate monitor (ISERM) maintains a counter to estimate the PDU rate error rate. The ISERM counter exceeded the estimated threshold.
0x61	Remote NE Loopback	(Level = MAJOR) Indicates the link is in loopback
0x62	Remote NE Loopback Cleared	Indicates the link was in loopback and now the loopback has been de-activated.
0x70	Congestion Level 0 to 1	MSU traffic on the link has reached congestion level 1.
0x71	Congestion Level 1 to 2	MSU traffic on the link has reached congestion level 2.
0x72	Congestion Level 2 to 3	MSU traffic on the link has reached congestion level 3.
0x73	Congestion Level 3 to 2	The congestion has fallen to level 2.
0x74	Congestion Level 2 to 1	The congestion has fallen to level 1.
0x75	Congestion has cleared	The congestion state of a link has been resolved.
0x76	Discard Level 0 to 1	Messages with an SIO priority of 0 are being discarded.
0x77	Discard Level 1 to 2	Messages with an SIO priority of 0 or 1 are being discarded.
0x78	Discard Level 2 to 3	Messages with an SIO priority of 0, 1 or 2 are being discarded.
0x79	Discard Level 3 to 2	Congestion is clearing and the level has fallen to level 2.
0x7A	Discard Level 2 to 1	Congestion is clearing and the level has fallen to level 1.
0x7B	Discard has cleared	No messages are being discarded. Overflow has reached level 0.
0x80	SIO Received	SIO message received at L2
0x81	SIO Transmitted	SIO message transmitted at L2
0x82	SIN Received	SIN message received at L2
0x83	SIN Transmitted	SIN message transmitted at L2
0x84	SIE Received	SIE message received at L2
0x85	SIE Transmitted	SIE message transmitted at L2

Code	Indication	Description
0x86	SIOS Received	SIOS message received at L2
0x87	SIOS Transmitted	SIOS message transmitted at L2
0x88	SIPO Received	SIPO message received at L2
0x89	SIPO Transmitted	SIPO message transmitted at L2
0x8A	SIB Received	SIB message received at L2
0x8B	SIB Transmitted	SIB message transmitted at L2
0x8C	FISU Received	FISU message received at L2
0x8D	FISU Transmitted	FISU message transmitted at L2
0x8E	No Data	No data being received at L2
0x90	Out of Service sent	Out of Service event sent by SSCF
0x91	Out of Service received	Out of Service event Received by SSCF
0x92	Processor Outage sent	Processor Outage event sent by SSCF
0x93	Processor Outage received	Processor Outage event received by SSCF
0x94	In Service sent	In Service event sent by SSCF
0x95	In Service received	In Service event received by SSCF
0x96	Normal sent	Normal event sent by SSCF
0x97	Normal received	Normal event received by SSCF
0x98	Emergency sent	Emergency event sent by SSCF
0x99	Emergency received	Emergency event received by SSCF
0x9A	Alignment Not Successful sent	Alignment Not Successful event sent by SSCF
0x9B	Alignment not successful Rcvd.	Alignment not successful event Rcvd. By SSCF
0x9C	Mgmt Initiated sent	Mgmt Initiated event sent by SSCF
0x9D	Mgmt Initiated received	Mgmt Initiated event received by SSCF
0x9E	Protocol Error sent	Protocol Error event sent by SSCF
0x9F	Protocol Error received	Protocol Error event received by SSCF
0xA0	Proving Not Successful sent	Proving Not Successful event sent by SSCF
0xA1	Proving Not Successful received	Proving Not Successful event rcvd by SSCF

Table 11: Events and Corresponding Event Codes

Octet twenty in event message **1700** contains an event count. The event count indicates the number of times this same event was seen between the first occurrence (indicated by the timestamp value) and the generation of this event message.

Octets twenty-one and twenty-two in event message **1700** contain the event data length. The event data length indicates the length of the event data field that follows. The octets beginning from twenty-three to the length specified in the event message's event data length field contain event data. Event data may be any data used by an application to describe an event. For example, event data may include a text string, such as "link down" for communicating event information to a human operator.

As illustrated in Figure 17, for efficiency purposes, event message **1700** may carry multiple events. In order to carry multiple events, the event information from the timestamp field to the event data field may be repeated..

A link data message is used to carry link data from network monitoring client **610** to network monitoring processors **106**. Figure 18 shown below illustrates an example of a link data message **1800** suitable for use by embodiments of the present invention. In Figure 18, link data message **1800** includes a header portion **1102** and a data portion **1104**. Header portion **1102** preferably includes a code (0x06) that identifies the message as a link data message. Data portion **1104** includes various fields for carrying link data, which will now be explained in more detail.

Octets eight and nine in the link data message **1800** contain a card ID. The card ID indicates the card in the routing node being monitored that sent the link data message. The card ID may be a slot identifier that indicates the particular slot in the routing node in which the card is located.

Octet ten in link data message **1800** contains a card port identifier. The card port identifier identifies the port on the routing node being monitored from which the link data was sent or received.

Octets eleven through eighteen in link data message **1800** contain a timestamp. The timestamp represents the time the MSU was received or transmitted by the routing node being monitored. The timestamp may be in any suitable format. For example, the timestamp may be in the Unix timespec format of thirty-two (32) bits for seconds since January 1st, 1900 and thirty-two (32) bits for nanoseconds.

Octet nineteen in the link data message **1800** contains a direction value. The direction value indicates the traffic direction of the MSU when processed by the routing node being monitored. Table 12 shown below illustrates exemplary direction value codings that may be used.

Coding	Indication
0x01	Transmitted by Routing Node
0x02	Received by Routing Node

Table 12: Direction Codes

Octets twenty and twenty-one in link data message **1800** contain the data length. The data length octets indicate the length of the MSU data fields that follow. The octets beginning from twenty-two to the length specified in the link data message's data length field contain the MSU data. The MSU data may be stored in any suitable order, such as link wire order (i.e., it is transmitted as it was received) and contains the MSU fields BSN through SIF inclusive. Link data message **1800** may contain multiple MSUs. The actual MSU information, from the timestamp through the MSU Data, may be repeated.

A service change message may be used by network monitoring processor **106** to alter the network monitoring service being provided. Figure 19 illustrates an exemplary network monitoring service change message format suitable for use by embodiments of the present invention. In Figure 19, service change message **1900** includes a header portion **1102** and a data portion **1104**. Header portion **1102** preferably includes a value (0x07) that identifies the message as a service change message. Data portion **1104** includes various fields relating to changing network monitoring service, which will now be described in further detail.

Octets eight and nine in service change message **1900** contain the card ID. The card ID identifies the card in the routing node being monitored that the service change will affect. The card ID may be any suitable code that identifies the card. In one example, the card ID is a code that identifies the card slot in the routing node being monitored.

Octet ten in service change message **1900** contains a port identifier. The port identifier identifies the port on the routing node being monitored to which the service change applies.

Octet eleven in service change message **1900** contains the service mode. The service mode is used to indicate the new type of service granted by network monitoring processor **106**. Table 9 illustrated above includes exemplary service modes and corresponding codings that may be used in the service mode field.

Network monitoring processor **106** may use service change message **1900** to dynamically change the network monitoring service being provided. For example, network monitoring processor **106** may send a first service change message to start the flow of MSUs and a second service change message to end the flow of MSUs. In another example, network monitoring processor **106** may send a service change message to change the network monitoring service being provided from MSU copy service to alarm service or vice versa. In yet another example, network monitoring processor **106** may send a service change message to change the flow of MSUs to transmitted only MSUs or received only MSUs. Thus, service change message **1900** allows an operator or any application to modify on the fly the type of network monitoring service being provided.

Thus, Figures 11-19 illustrate that the network monitoring communications protocol according to the present invention includes a plurality of message types, each having a specific network monitoring function. These message types greatly decrease the time required to configure or change network monitoring service when the configuration of a network or routing node being monitored changes. As a result, network monitoring efficiency is increased.

Exemplary Network Deployment

An automatically configurable network monitoring system according to an embodiment of the present invention may be deployed at various locations in a telecommunications signaling network to monitor signaling messages. Figure 20 illustrates exemplary locations in a signaling network in which an automatically configurable network monitoring system according to the present invention may be deployed. In Figure 20, completely probeless automatically configurable network monitoring systems **2000** and **2002** are deployed at STPs **2004** and **2006** to monitoring signaling links between STPs **2004** and **2006** and SSPs **2008** and **2010**. In this example, automatically configurable network monitoring systems **2000** and **2002** emulate probe-based systems. However, as described above with respect to Figures 3-5, external link probes are not required because network monitoring system hardware may be located in the same shelf or in an adjacent shelf as each signal transfer point and connected directly to the signal transfer point. A terminal(not shown) may also be included to provide operator access to probeless automatically configurable network monitoring systems **2000** and **2002**.

Probeless automatically configurable network monitoring systems **2000** and **2002** may be used with one or more probe-based network monitoring systems. In Figure 20, probe-based network monitoring units **2012** and **2014** and associated data recorders (not shown) may be deployed at STPs **2022** and **2024** to monitor messages sent between STPs **2016** and **2018** and MSC **2020** and SCP **2022**. An exemplary hardware platform suitable for use as probe-based network monitoring units **2012** and **2014** is the i3000 or i2000 available from Tekelec of Calabasas, California. The associated data recorders may be implemented using Unix-based workstations, such as SUN servers.

An additional probe-based network monitoring unit **2024** and associated data recorder **2026** may be included to record data transmitted between MSC **2020** and base station **2028**. An exemplary hardware platform suitable for use as probe-based network monitoring system **2024** is the i2000 available from Tekelec of Calabasas, California.

As described above with respect to Figure 1, automatically configurable network monitoring systems **2000** and **2002** may communicate with one or more network monitoring applications to provide various network monitoring services. In Figure 20, network monitoring systems **2000, 2002, 2012, 2014,** and **2024** communicate with server farm **110**, which may be located at a network operations center (NOC). As stated above with regard to Figure 1, server farm **110** includes a network monitoring server **114**, a data gateway server **116**, an alarm server **118**, and a database server **120**. Network monitoring server **114** performs the following functions: real time signaling link status reporting, real time signaling link state reporting, real time protocol analysis, such as call tracing, filtering, and decoding, traffic report generation, and real time event reporting. Data gateway server **116** receives MSU fragments, formats the MSU fragments into CDRs and sends the CDRs to applications, such as fraud detection applications, billing verification applications, etc. Alarm server **118** collects event message reports and other events that report signaling link errors and displays alarms to the user. Database server **120** is connected to network monitoring server **114**. Network monitoring server **114** generates canned traffic reports in flat ASCII format. Some end users may desire to generate customized traffic reports. Hence, database server **120** stores the data collected by network monitoring server **114** in a database, such as an Oracle database. A database front end, such as Crystal Reports available from Seagate Software may be used along with database server **120** to generated customized reports. Server farm **110** may be located at a network operations center or a telecommunications administration center for performing network operation and administration functions based on data provided by the network monitoring systems illustrated in Figure 20.

Thus, as illustrated in Figure 20, a probeless automatically configurable network monitoring system may be deployed in conjunction with probe-based systems to provide a complete view of the network being monitored. In addition, the automatically configurable network monitoring system according to the present invention may emulate conventional probe-based systems by replacing conventional probe-based systems at an STP and copying MSUs from signaling links previously monitored by probe-based systems. Finally, because the automatically configurable network monitoring systems according to the present invention can be configured and altered automatically using the network monitoring communications protocol described herein, the need for skilled network monitoring personnel at the network monitoring site is reduced.

It will be understood that various details of the invention may be changed without departing from the scope of the invention. Furthermore, the foregoing description is for the purpose of illustration only, and not for the purpose of limitation—the invention being defined by the claims.

CLAIMS

What is claimed is:

1. A method for automatically configuring a network monitoring system to monitor signaling links connected to a network routing node:

   (a) instantiating a plurality of network monitoring servers on a plurality of network monitoring devices, each network monitoring server being provisioned to monitor a predetermined set of signaling links;

   (b) instantiating a network monitoring client on the network routing node, the network monitoring client being associated with one or more signaling links connected to the network routing node;

   (c) sending a network monitoring service request from the network monitoring client to the network monitoring servers, the network monitoring service request including information for identifying the signaling link or links for which network monitoring service is being requested;

   (d) at the network monitoring servers, determining whether the network monitoring service request relates to one of the signaling links in the predetermined set of signaling links for which each server is provisioned to monitor;

   (e) in response to determining that the network monitoring request relates to a signaling link for which a network monitoring server is provisioned to monitor, sending a network monitoring service accept message from that network monitoring server to the network monitoring client; and

   (f) establishing a network monitoring connection between the network monitoring client and the accepting network monitoring server.

2. The method of claim 1 wherein instantiating a network monitoring client on a network routing node includes instantiating a network monitoring client on a signal transfer point.

3. The method of claim 1 wherein instantiating a network monitoring client on a network routing node includes instantiating a network monitoring client on an SS7/IP signaling gateway.

4. The method of claim 2 wherein instantiating a plurality of network monitoring servers includes instantiating a plurality of network monitoring servers on a plurality of adjunct processors coupled to the signal transfer point.

5. The method of claim 3 wherein instantiating a plurality of network monitoring servers includes instantiating a plurality of network monitoring servers on a plurality of adjunct processors coupled to the SS7/IP gateway.

6. The method of claim 1 wherein sending a network monitoring service request from the network monitoring client to the network monitoring servers includes sending a request for transmitting signaling link data from the network monitoring client to the network monitoring servers.

7. The method of claim 1 wherein sending a network monitoring service request from the network monitoring client to the network monitoring servers includes sending a request for transmitting system alarm data from the network monitoring client to the network monitoring servers.

8. The method of claim 1 wherein sending a network monitoring service request from the network monitoring client to the network monitoring servers includes broadcasting the network monitoring service request from the network monitoring client to the network monitoring servers.

9. The method of claim 8 wherein broadcasting the network monitoring service request includes broadcasting a UDP message to the network monitoring servers.

10. The method of claim 1 wherein sending a network monitoring service request from the network monitoring client to the network monitoring servers includes multicasting the network monitoring service request from the network monitoring client to the network monitoring servers.

11. The method of claim 1 wherein establishing a network monitoring connection includes establishing a TCP connection between the network monitoring client and the responding network monitoring server.

12. The method of claim 11 wherein establishing the network monitoring connection comprises, after establishing the TCP connection, sending a provisioning information message from the network monitoring client to the network monitoring server, the provisioning information message including signaling link data for verifying the signaling link identification information sent in the network monitoring request message.

13. An automatically-configurable network monitoring system comprising:

(a) a network routing node including link interface modules for sending and receiving messages over external signaling links and for copying at least some of the messages, each of the link interface modules including a network monitoring client associated with one or more signaling links, wherein the network monitoring clients are adapted to generate network monitoring service request messages including provisioning information for their respective signaling links; and

(b) a plurality of network monitoring processors coupled to the network routing node, each of the network monitoring processors including one or more network monitoring servers, wherein the network monitoring servers obtain signaling link configuration information from the network monitoring service request messages.

14. The network monitoring system of claim 13 wherein the network routing node comprises a signal transfer point.

15. The network monitoring system of claim 13 wherein the network routing node comprises an SS7/IP gateway.

16. The network monitoring system of claim 13 wherein the link interface modules comprise SS7 link interface modules.

17. The network monitoring system of claim 13 wherein the link interface modules comprise data communications modules capable of sending and receiving IP messages.

18. The network monitoring system of claim 17 wherein each of the IP messages comprise transport adapter layer interface messages, and wherein the link interface modules are adapted to copy and send the transport adapter layer interface messages to the network monitoring servers.

19. The network monitoring system of claim 13 wherein the network monitoring clients are adapted to broadcast the network monitoring service request messages to the network monitoring servers.

20. The network monitoring system of claim 19 wherein the network monitoring servers are each provisioned to monitoring a predetermined set of signaling links connected to the network routing node and wherein the network monitoring server provisioned to monitor the signaling links specified in a network monitoring service request message responds to the network monitoring service request message.

21. The network monitoring system of claim 13 comprising a plurality of remote servers coupled to the network monitoring processors for receiving copied signaling messages from the network monitoring processors and performing a plurality of network monitoring functions based on the copied signaling messages.

22. The network monitoring system of claim 21 wherein the remote servers include a network monitoring server for performing real time link state reporting, real time link status reporting, and real time protocol analysis.

23. The network monitoring system of claim 21 wherein the remote servers include a data gateway server for generating call detail records.

24. The network monitoring system of claim 21 wherein the remote servers include an alarm server for receiving event notifications from the network monitoring processors and for generating alarms to a user based on the event reports.

25. The network monitoring system of claim 22 wherein the remote servers include a database server coupled to the network monitoring server for storing signaling message information in a database and allowing a user to generate customized reports based on the information stored in the database.

26. A probeless network monitoring system comprising:

(a) a signal transfer point including a plurality of link interface modules for sending and receiving messages via external signaling links, each link interface module including a client for requesting network monitoring service; and

(b) a plurality of general-purpose processors coupled to the signal transfer point without using external signaling link probes, each general purpose processor including a server for responding to the requests received from the network monitoring clients.

27. The probeless network monitoring device of claim 26 the network monitoring clients are adapted to broadcast network monitoring service request messages to the network monitoring servers.

28. The probeless network monitoring device of claim 27 wherein the network monitoring service request messages include signaling link identification information for identifying signaling links for which network monitoring service is requested.

29. The probeless network monitoring device of claim 28 wherein each of the network monitoring servers is provisioned to service a predetermined set of signaling links.

30. The probeless network monitoring system of claim 29 wherein the predetermined sets of signaling links are exclusive of each other.

31. The probeless network monitoring system of claim 26 wherein the signal transfer point and the general purpose processors are located in the same telecommunications equipment frame.

32. The probeless networ monitoring system of claim 26 wherein the signal trannsfer point and the general purpose processors are located in separate telecommunications equipment frames.

33. The probeless network monitoring system of claim 26 wherein the signal transfer point and the general purpose processors are connected via Ethernet.

34. The probeless network monitoring system of claim 26 wherein the signal transfer point includes a bus for interconnecting the link interface modules.

35. The probeless network monitoring system of claim 35 comprising a plurality of network monitoring transport cards coupled to the bus for routing network monitoring messages between the link interface modules and the general purpose processors.

36. A computer-implemented network monitoring communications protocol for communicating network monitoring messages between a routing node being monitored and a network monitoring processor, the computer-implemented communications protocol comprising:

(a) computer code adapted to execute on a network routing node for automatically sending network monitoring service request messages to a network monitoring processor; and

(b) computer code adapted to execute on a network monitoring processor for receiving service request messages and formulating service response messages for granting or denying network monitoring service requests based on the service request messages.

37. The computer-implemented network monitoring communications protocol of claim 36 wherein the service request messages each include a header portion for identifying the message as a service request message and a data portion containing signaling link information regarding the signaling link for which network monitoring service is being requested.

38. The computer-implemented network monitoring communications protocol of claim 36 wherein the computer code adapted to execute on the network monitoring processor includes computer-executable instructions for formulating a service accept message in response to

granting a service request, the service accept message including a header portion for identifying the message as a service accept message and a data portion including a network address of a network monitoring service providing entity.

39. The computer-implemented network monitoring communications protocol of claim 36 wherein the computer code adapted to execute on the network monitoring processor includes computer-executable instructions for formulating a service reject message in response to denying a service request, the service reject message including a header portion for identifying the message as a service reject message and a data portion including a code indicating a reason for denying the service request.

40. The computer-implemented network monitoring communications protocol of claim 39 wherein the computer code adapted to execute on the routing node includes computer-executable instructions for formulating a provisioning information message in response to receiving a service accept message, the provisioning information message including a header portion for identifying the message as a provisioning information message and a data portion for communication signaling link provisioning information to the network monitoring processor.

41. The computer-implemented network monitoring communications protocol of claim 36 wherein the computer code adapted to execute on the routing node includes computer-executable instructions for formulating and sending an event message to the network monitoring processor, the event message including a header portion for identifying the message as an event message and a data portion for communicating event information to the network monitoring processor.

42. The computer-implemented network monitoring communications protocol of claim 36 wherein the computer code adapted to execute on the routing node includes computer-executable instructions for formulating and sending a link data message, the link data message including a header portion for identifying the message as a link data

message and a data portion for carrying recorded signaling messages to the network monitoring processor.

43. The computer-implemented network monitoring communications protocol of claim 36 wherein the computer code adapted to execute on the network monitoring processor includes computer-executable instructions for formulating and sending a service change message, the service change message including a header portion for identifying the message as a service change message and a data portion for storing information for changing the type of network monitoring service being provided.

44. The computer-implemented network monitoring communications protocol of claim 36 wherein the computer code adapted to execute on the network monitoring processor and the computer code adapted to execute on the routing node each include computer executable instructions for sending formulating and sending heartbeat messages at predetermined time intervals.

45. The computer-implemented network monitoring communications protocol of claim 44 wherein the computer code adapted to execute on the network monitoring processor and the computer code adapted to execute on the routing node each include computer instructions for closing network monitoring sessions in response to failing to receive heartbeat messages from a peer node within a predetermined time period.

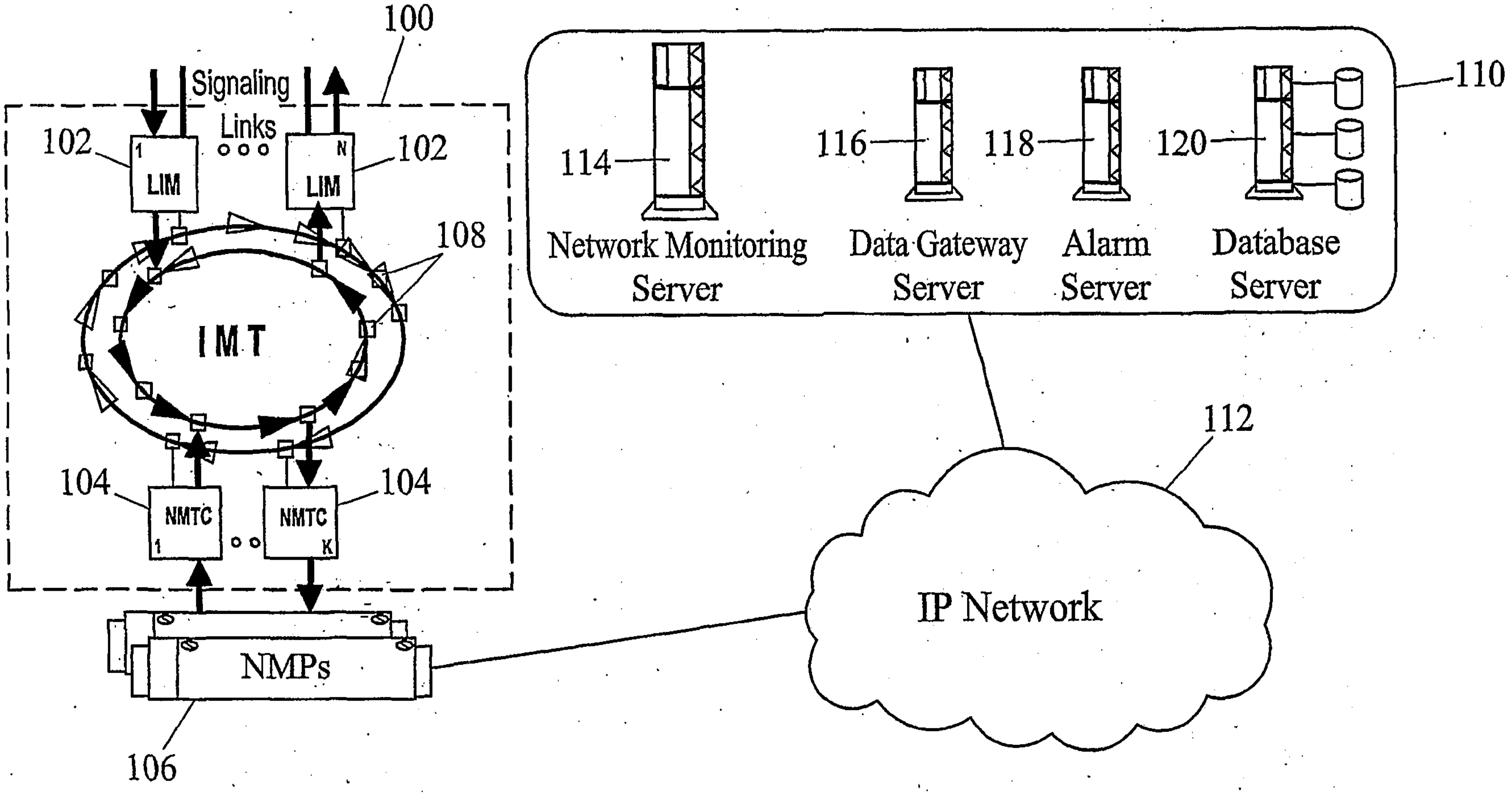

100
Signaling
Links
102
1
LIM
N
LIM
102
108
IMT
104
NMTC
1
NMTC
K
104
NMPs
106
114
Network Monitoring
Server
116
Data Gateway
Server
118
Alarm
Server
120
Database
Server
110
112
IP Network

FIG. 1

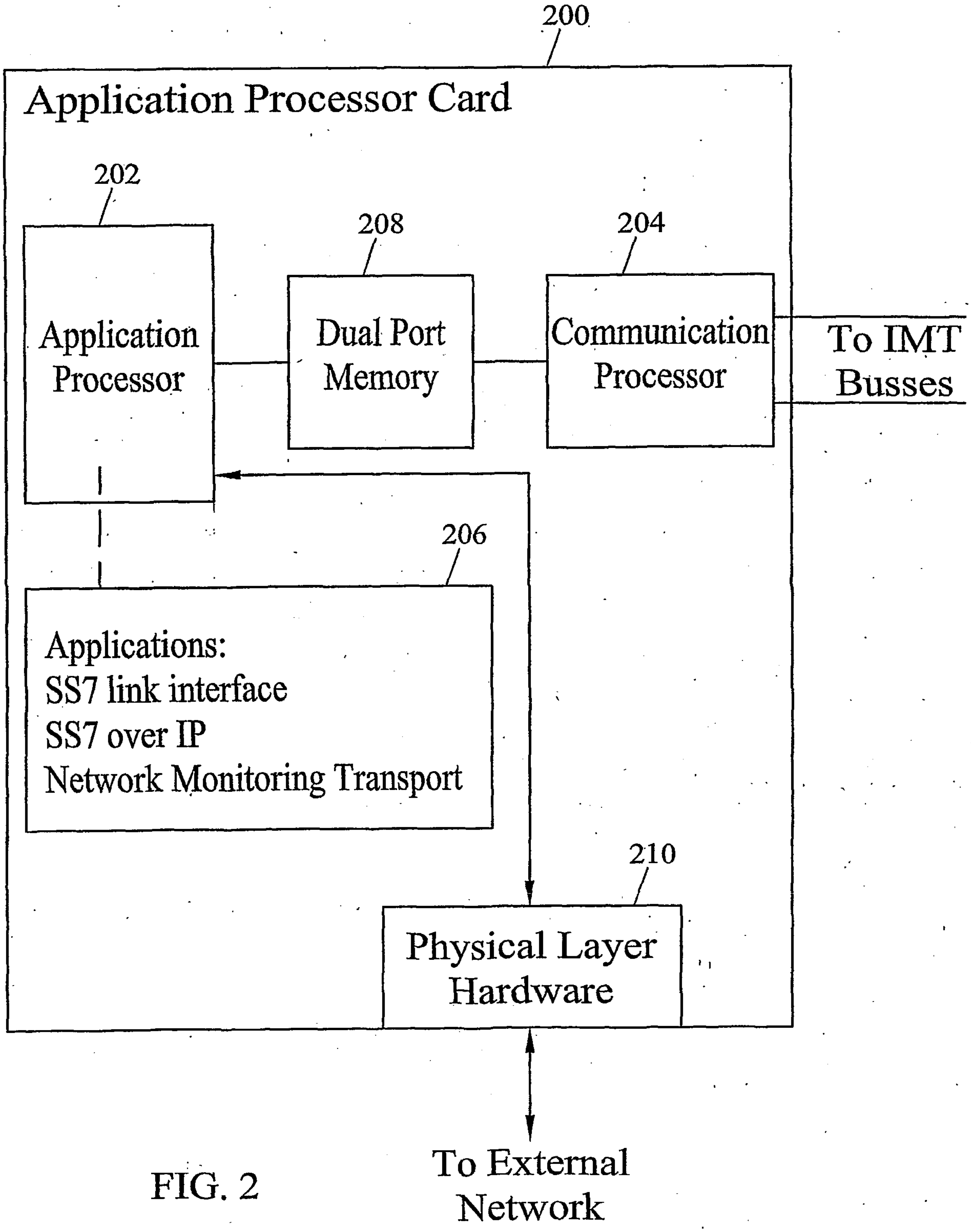

200
Application Processor Card
202
Application Processor
208
Dual Port Memory
204
Communication Processor
To IMT Busses
206
Applications:
SS7 link interface
SS7 over IP
Network Monitoring Transport
210
Physical Layer Hardware
To External Network

FIG. 2

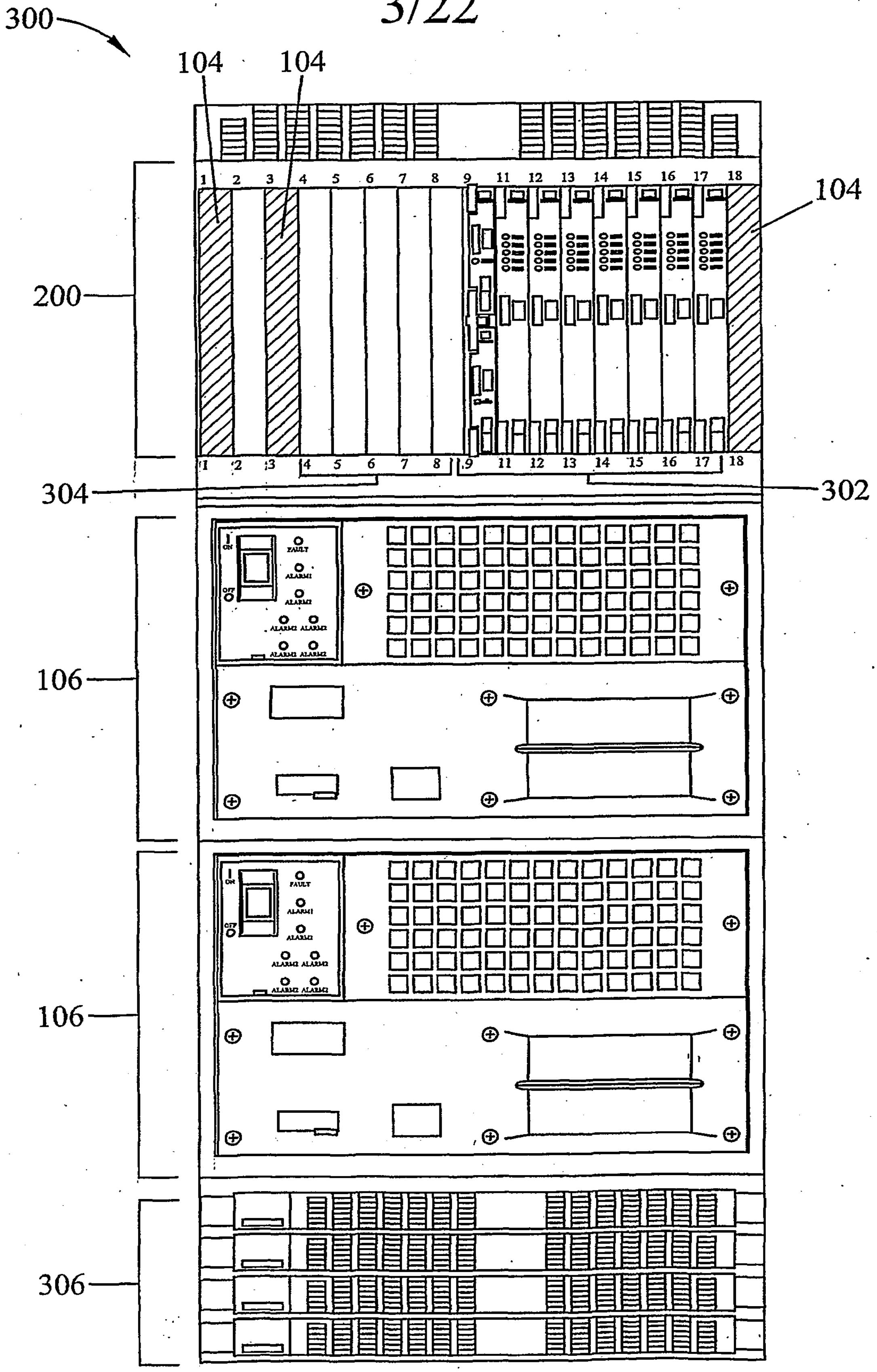

300
104
104
104
200
1 2 3 4 5 6 7 8 9 11 12 13 14 15 16 17 18
304
302
106
FAULT
ALARM1
ALARM2
ON
OFF
106
306

FIG. 3

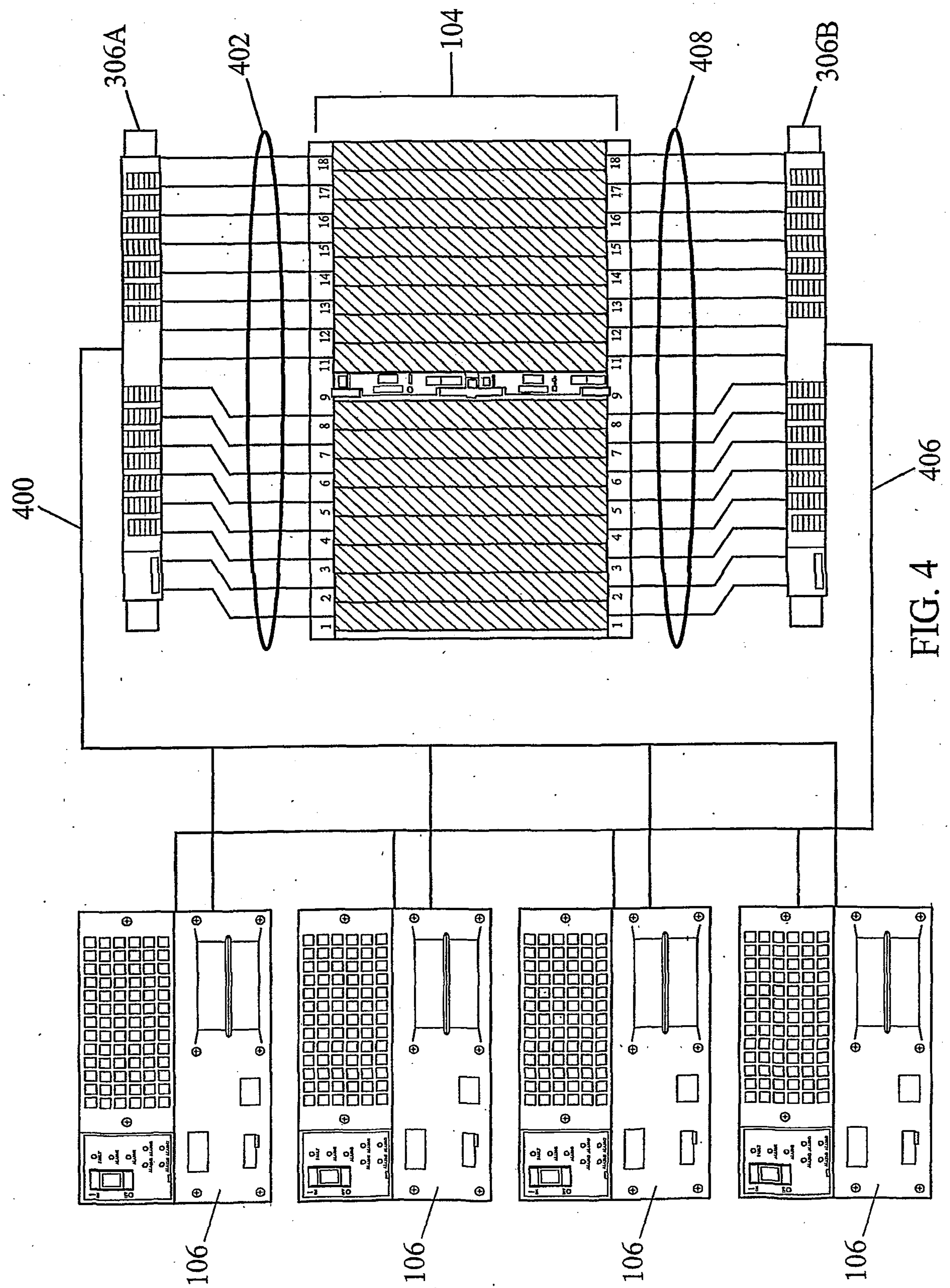

306A
402
104
408
306B
18
17
16
15
14
13
12
11
9
8
7
6
5
4
3
2
1
400
406
106
106
106
106

FIG. 4

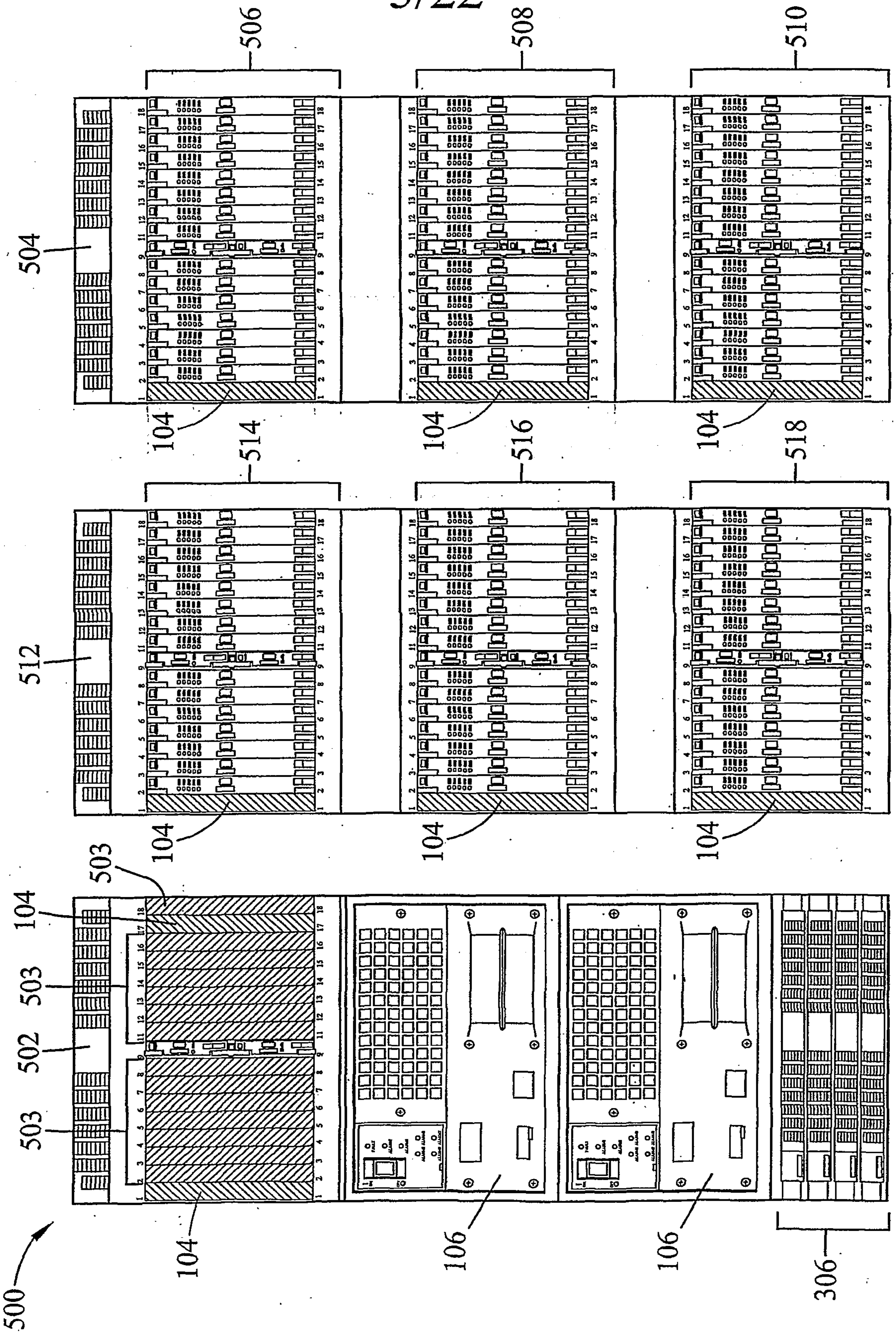

500
502
503
503
503
104
504
506
508
510
104
104
104
512
514
516
518
104
104
104
104
106
106
306
1
2
3
4
5
6
7
8
9
11
12
13
14
15
16
17
18

FIG. 5

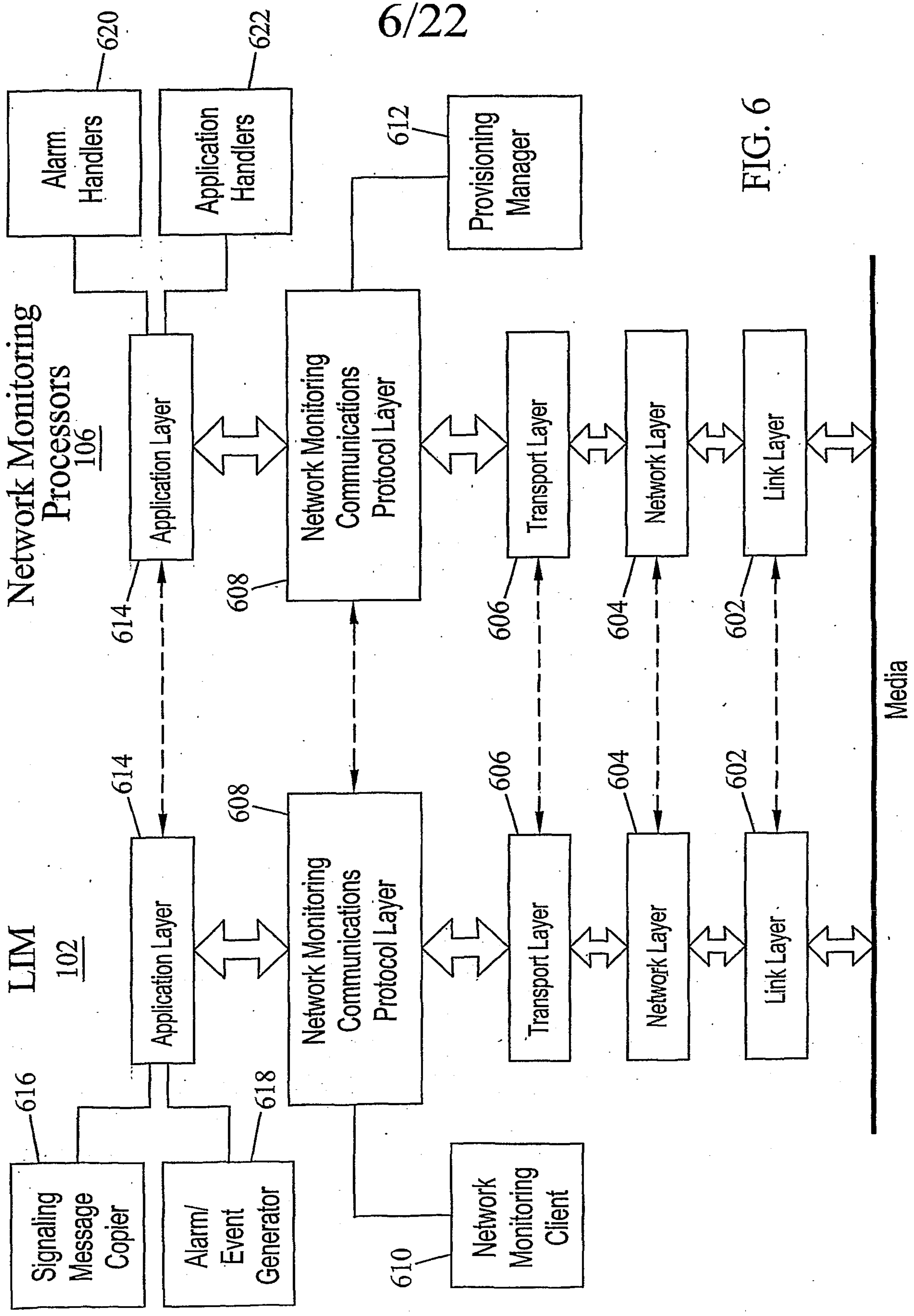

Network Monitoring Processors 106
Alarm Handlers
620
Application Handlers
622
Provisioning Manager
612
Application Layer
614
Network Monitoring Communications Protocol Layer
608
Transport Layer
606
Network Layer
604
Link Layer
602
LIM 102
Application Layer
614
Network Monitoring Communications Protocol Layer
608
Transport Layer
606
Network Layer
604
Link Layer
602
Signaling Message Copier
616
Alarm/Event Generator
618
Network Monitoring Client
610
Media

FIG. 6

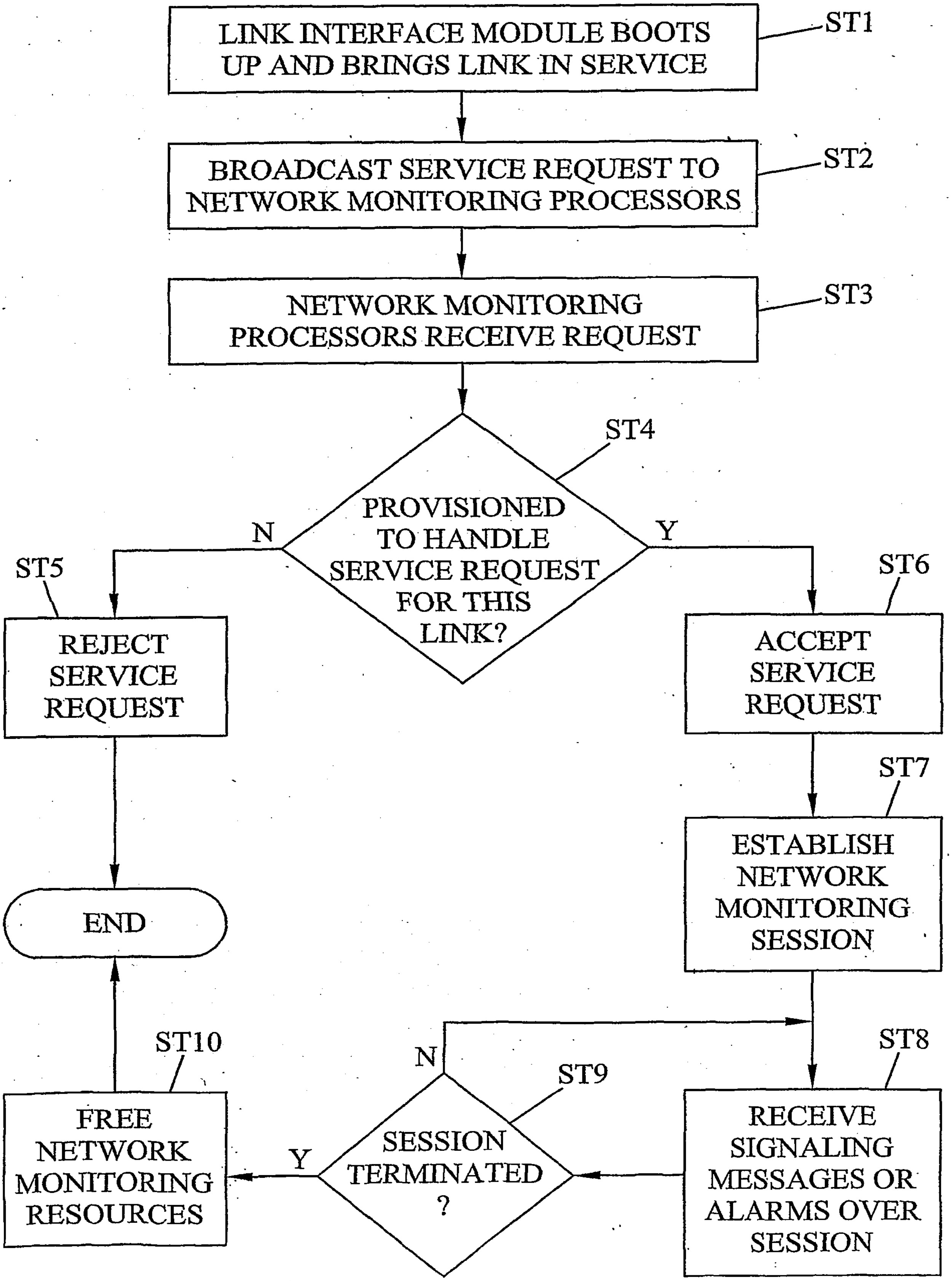

LINK INTERFACE MODULE BOOTS UP AND BRINGS LINK IN SERVICE
ST1
BROADCAST SERVICE REQUEST TO NETWORK MONITORING PROCESSORS
ST2
NETWORK MONITORING PROCESSORS RECEIVE REQUEST
ST3
PROVISIONED TO HANDLE SERVICE REQUEST FOR THIS LINK?
ST4
N
Y
ST5
REJECT SERVICE REQUEST
ST6
ACCEPT SERVICE REQUEST
ST7
ESTABLISH NETWORK MONITORING SESSION
END
ST8
RECEIVE SIGNALING MESSAGES OR ALARMS OVER SESSION
ST9
SESSION TERMINATED ?
N
Y
ST10
FREE NETWORK MONITORING RESOURCES

FIG. 7

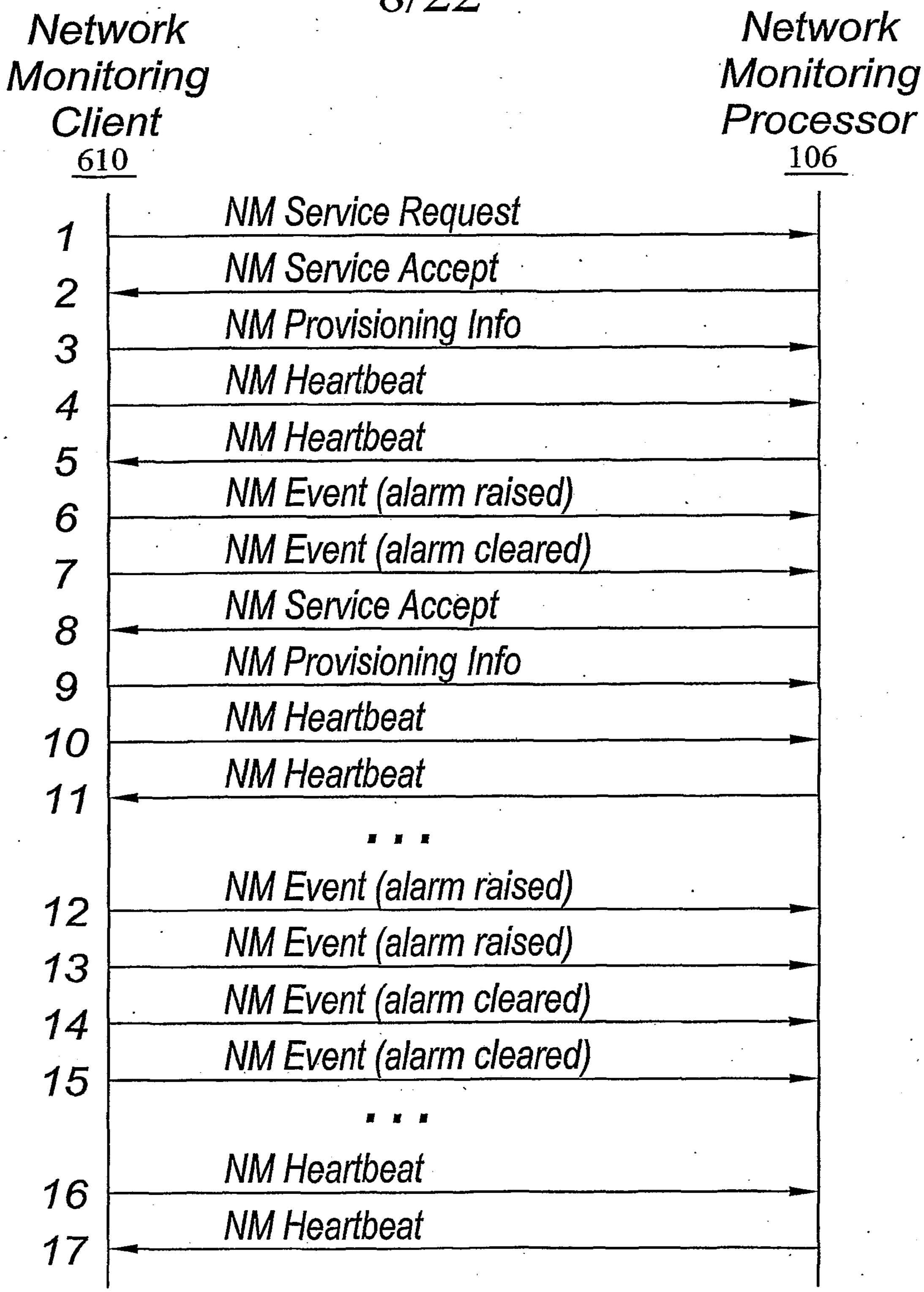

Network Monitoring Client
610
Network Monitoring Processor
106
1
NM Service Request
2
NM Service Accept
3
NM Provisioning Info
4
NM Heartbeat
5
NM Heartbeat
6
NM Event (alarm raised)
7
NM Event (alarm cleared)
8
NM Service Accept
9
NM Provisioning Info
10
NM Heartbeat
11
NM Heartbeat
. . .
12
NM Event (alarm raised)
13
NM Event (alarm raised)
14
NM Event (alarm cleared)
15
NM Event (alarm cleared)
. . .
16
NM Heartbeat
17
NM Heartbeat

FIG. 8

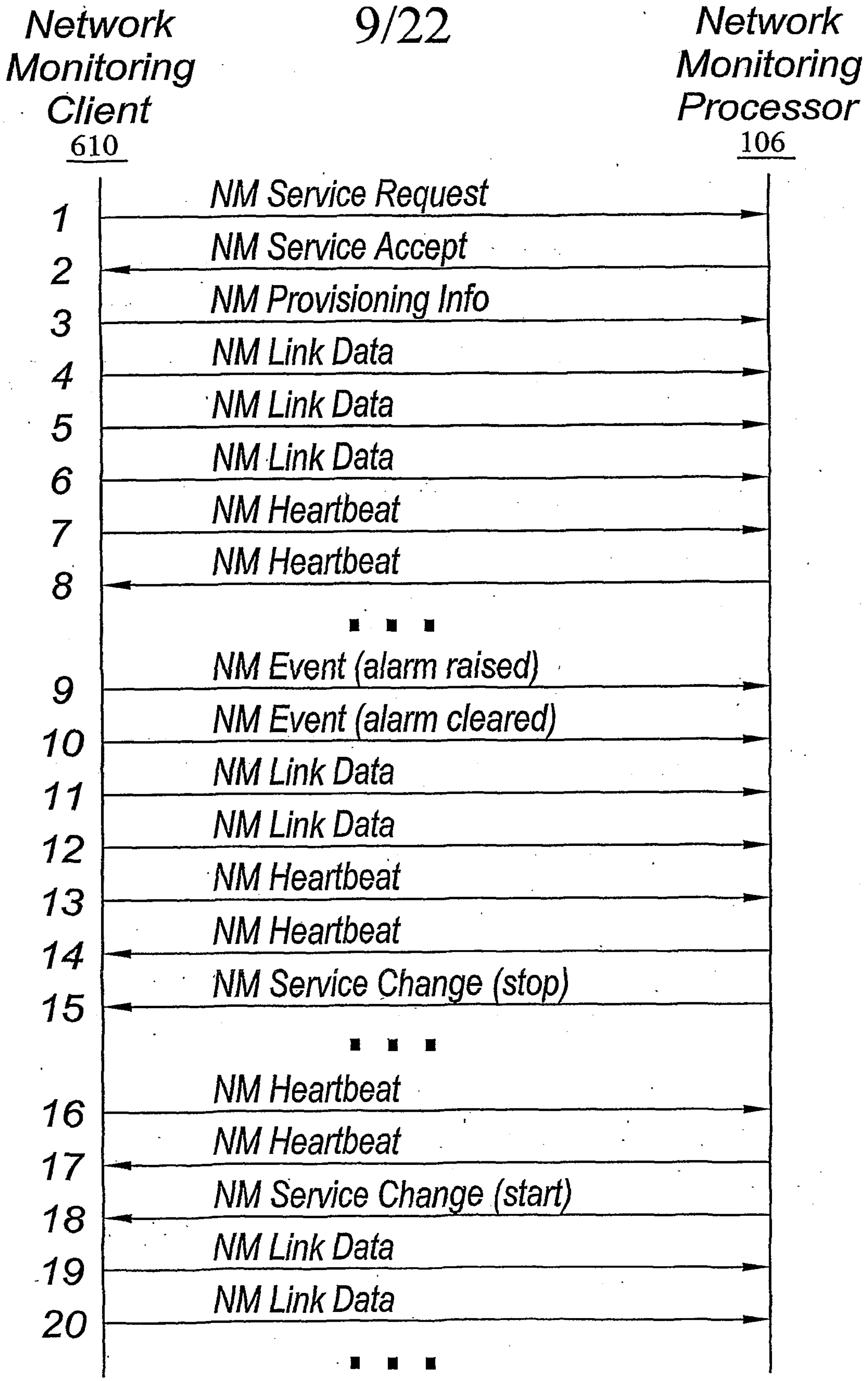

Network Monitoring Client
610
Network Monitoring Processor
106
1
NM Service Request
2
NM Service Accept
3
NM Provisioning Info
4
NM Link Data
5
NM Link Data
6
NM Link Data
7
NM Heartbeat
8
NM Heartbeat
9
NM Event (alarm raised)
10
NM Event (alarm cleared)
11
NM Link Data
12
NM Link Data
13
NM Heartbeat
14
NM Heartbeat
15
NM Service Change (stop)
16
NM Heartbeat
17
NM Heartbeat
18
NM Service Change (start)
19
NM Link Data
20
NM Link Data

FIG. 9

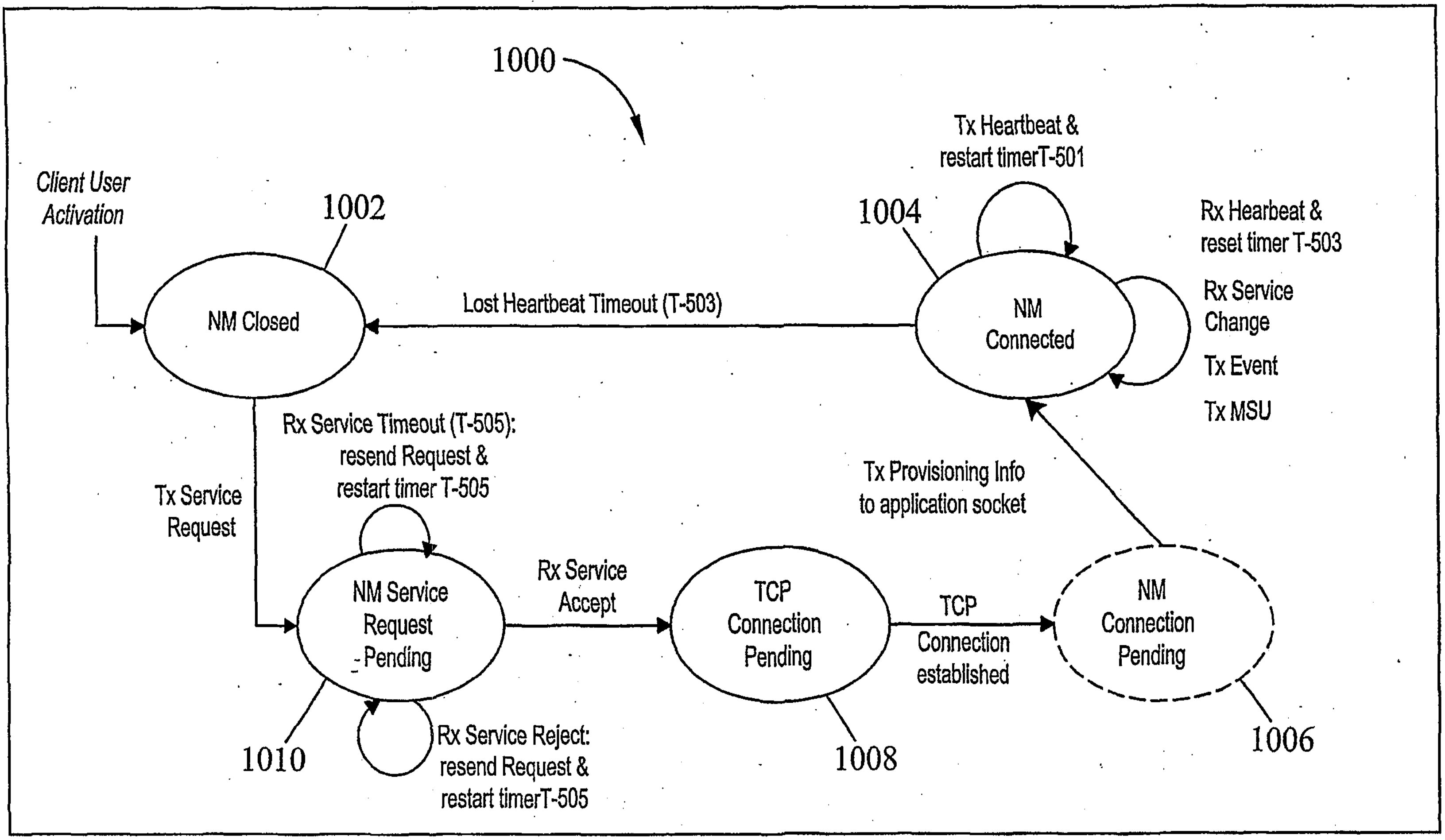

1000
Client User
Activation
1002
NM Closed
Lost Heartbeat Timeout (T-503)
1004
Tx Heartbeat &
restart timerT-501
NM
Connected
Rx Hearbeat &
reset timer T-503
Rx Service
Change
Tx Event
Tx MSU
Tx Service
Request
Rx Service Timeout (T-505):
resend Request &
restart timer T-505
NM Service
Request
Pending
1010
Rx Service Reject:
resend Request &
restart timerT-505
Rx Service
Accept
TCP
Connection
Pending
1008
TCP
Connection
established
Tx Provisioning Info
to application socket
NM
Connection
Pending
1006

FIG. 10A

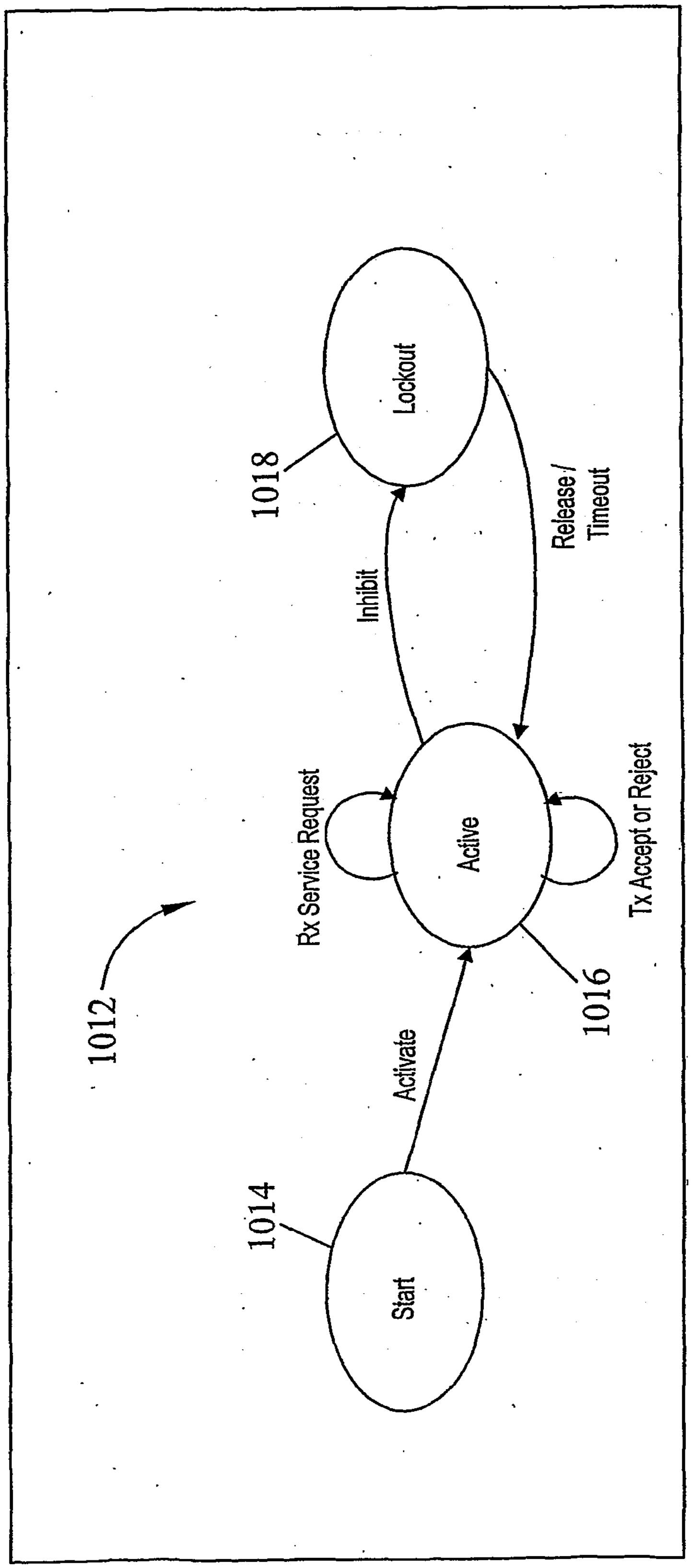

1012
Start
1014
Activate
Active
1016
Rx Service Request
Tx Accept or Reject
Inhibit
Release / Timeout
Lockout
1018

FIG. 10B

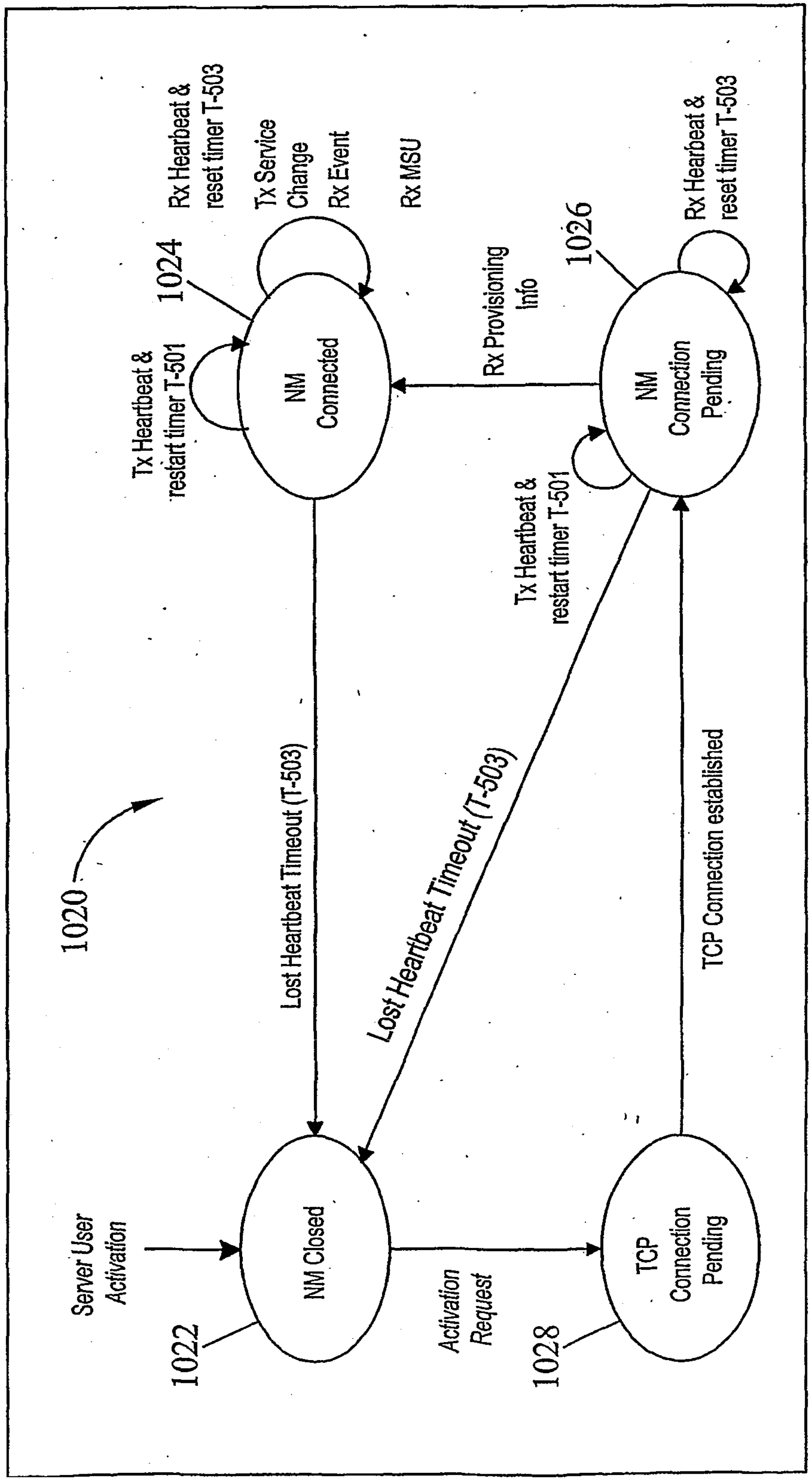
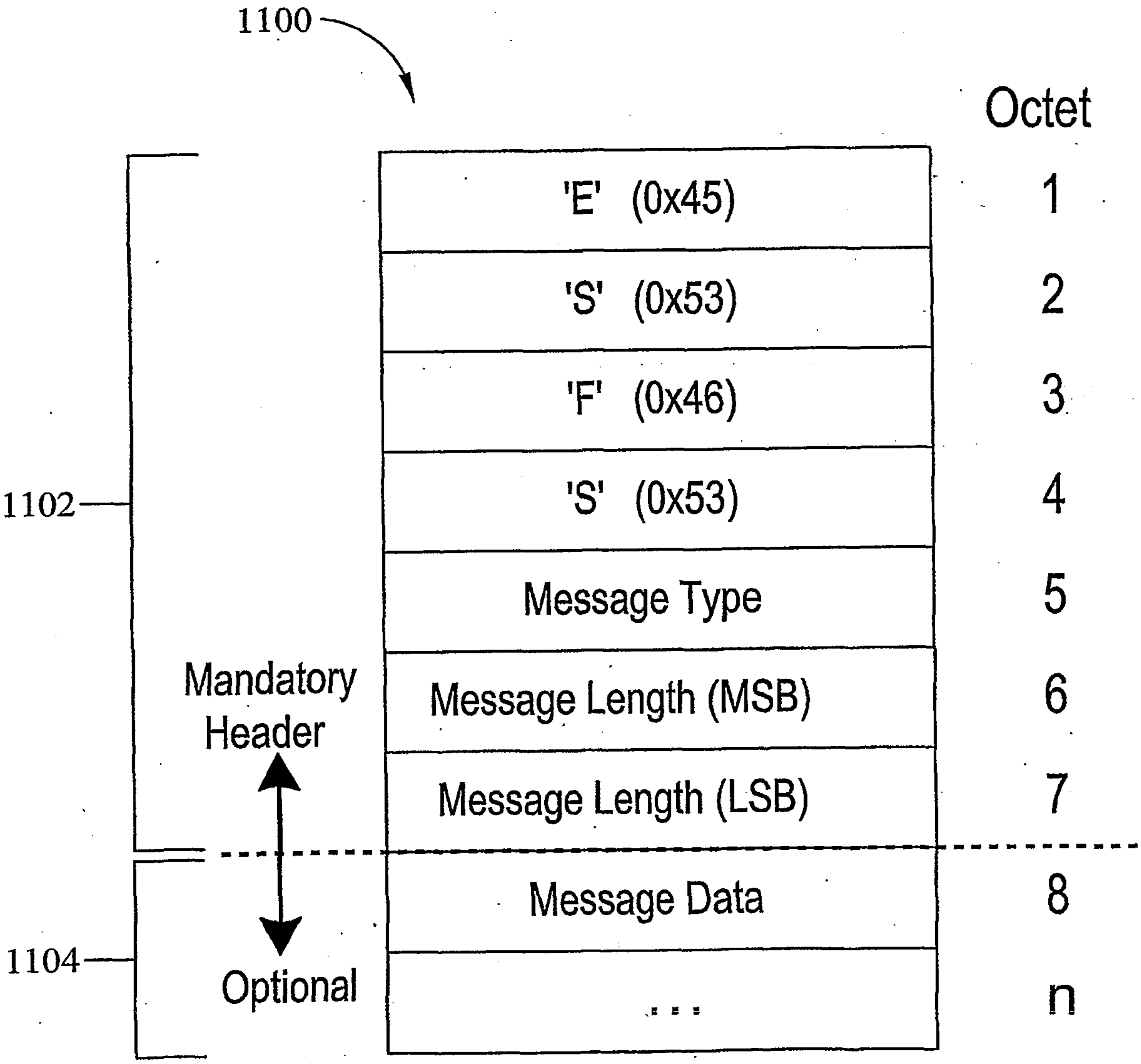
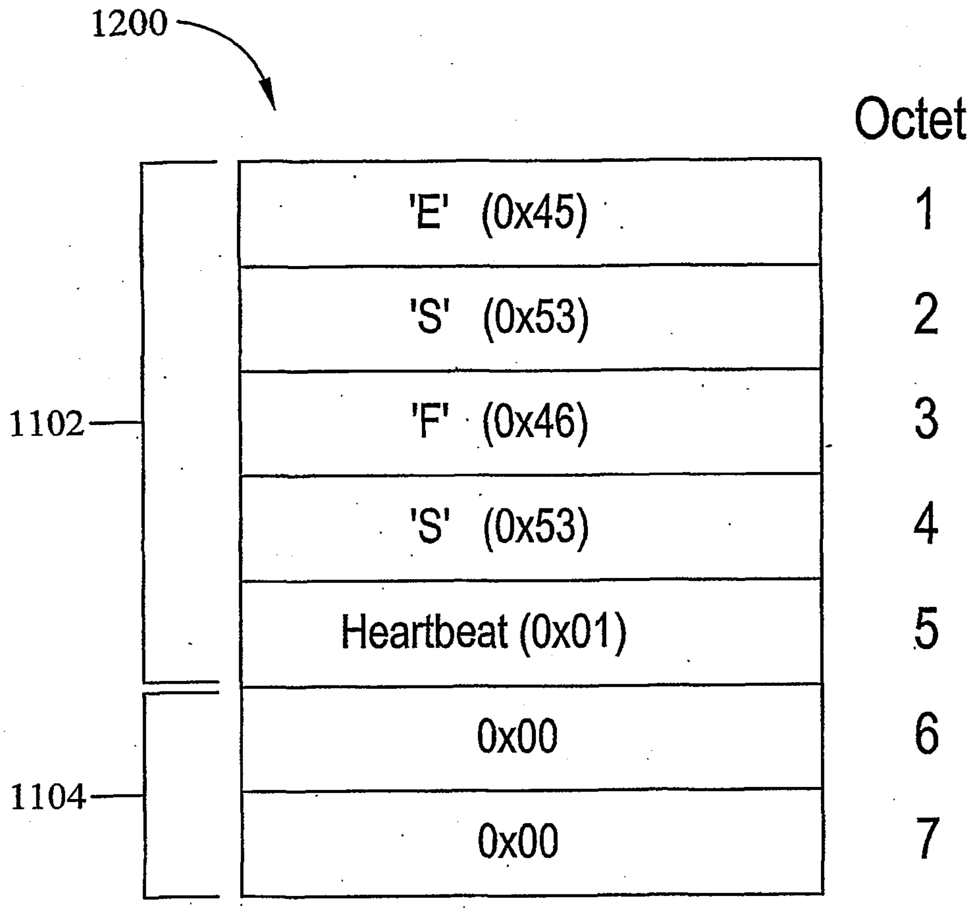

1020
Server User Activation
NM Closed
1022
Activation Request
TCP Connection Pending
1028
TCP Connection established
Lost Heartbeat Timeout (T-503)
Lost Heartbeat Timeout (T-503)
NM Connected
1024
Tx Heartbeat & restart timer T-501
Rx Heartbeat & reset timer T-503
Tx Service Change
Rx Event
Rx MSU
Rx Provisioning Info
NM Connection Pending
1026
Tx Heartbeat & restart timer T-501
Rx Heartbeat & reset timer T-503

FIG. 10C



	Octet
'E' (0x45)	1
'S' (0x53)	2
'F' (0x46)	3
'S' (0x53)	4
Message Type	5
Message Length (MSB)	6
Message Length (LSB)	7
Message Data	8
...	n

FIG. 11



	Octet
'E' (0x45)	1
'S' (0x53)	2
'F' (0x46)	3
'S' (0x53)	4
Heartbeat (0x01)	5
0x00	6
0x00	7

FIG. 12

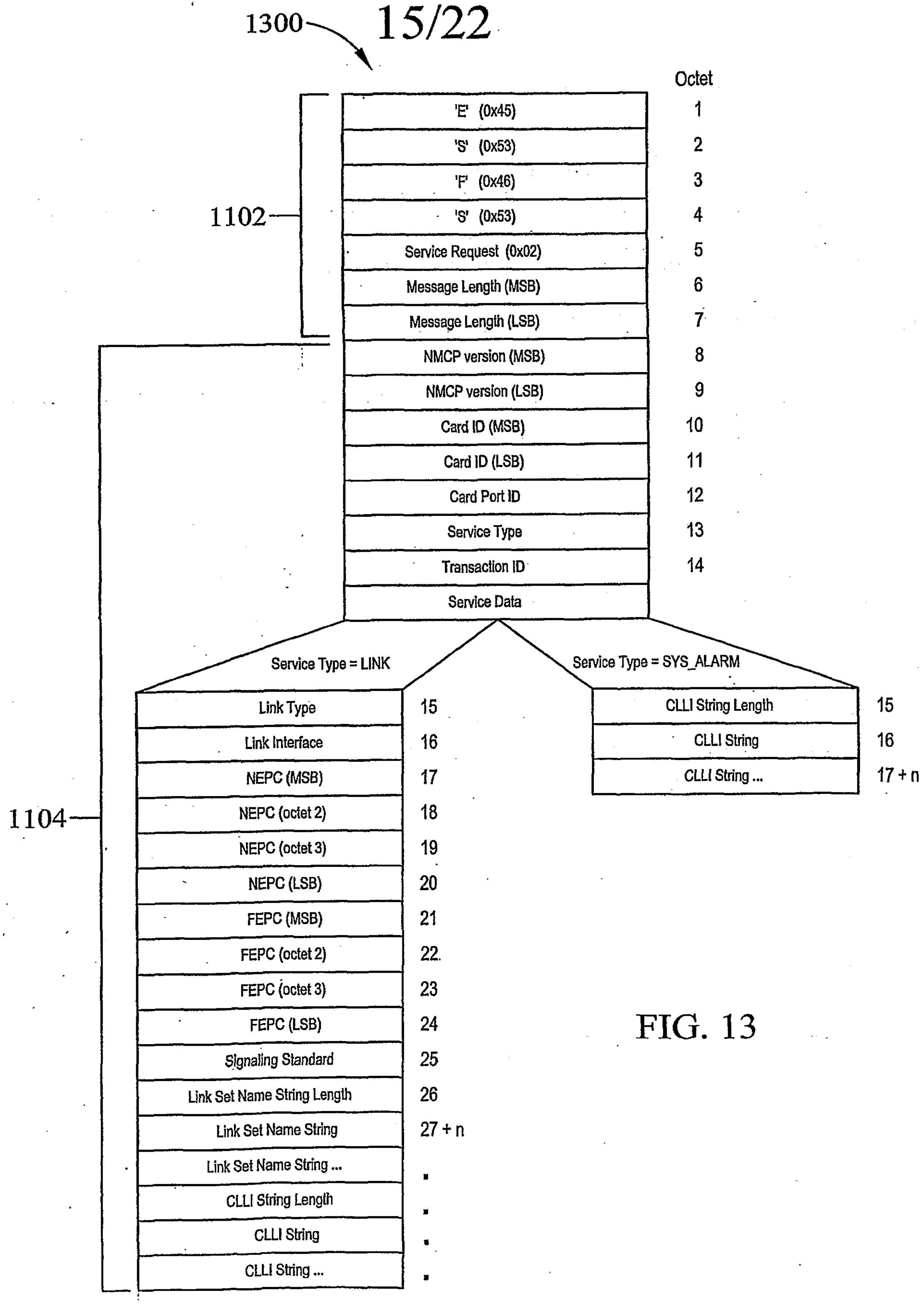
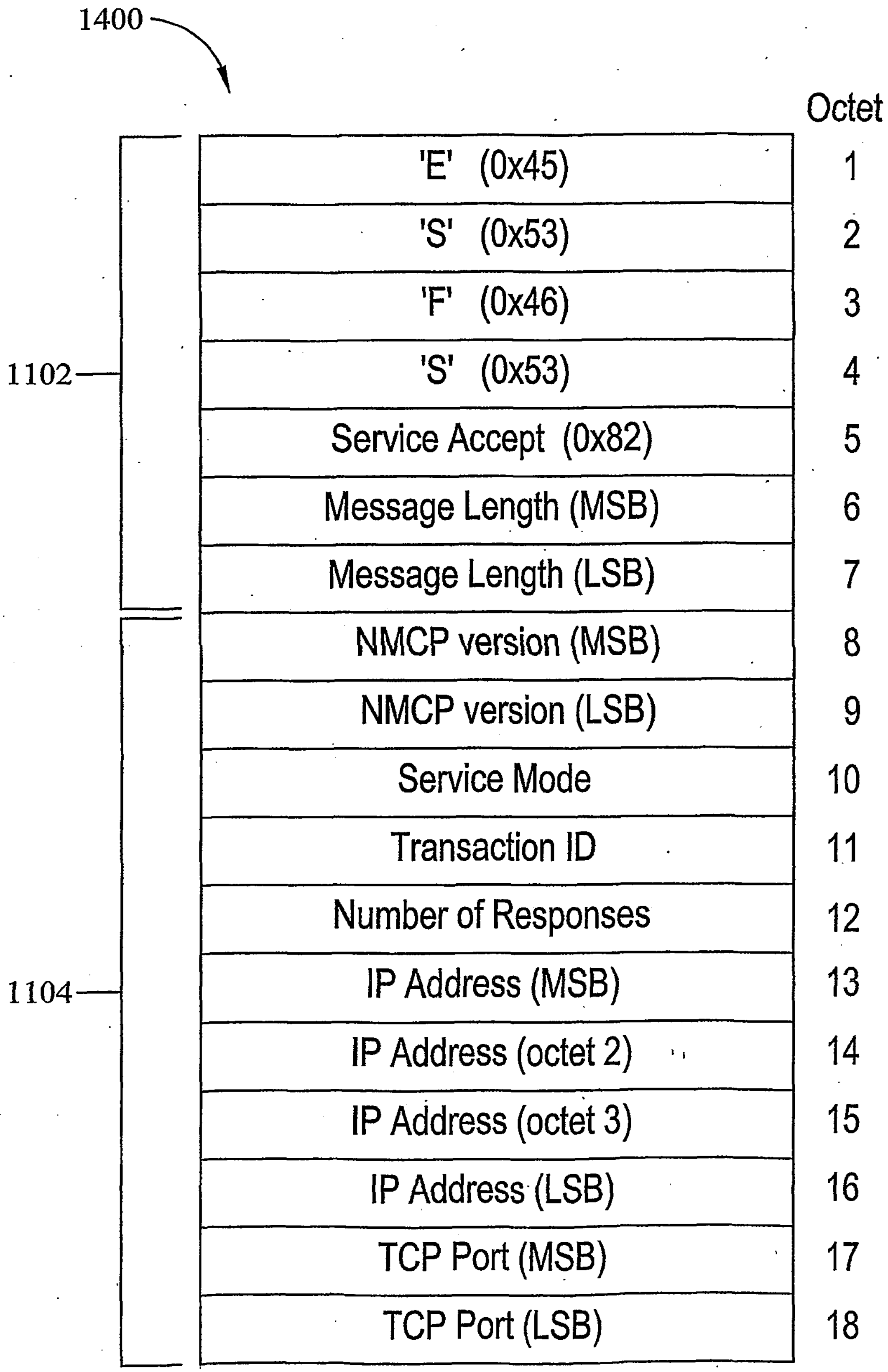
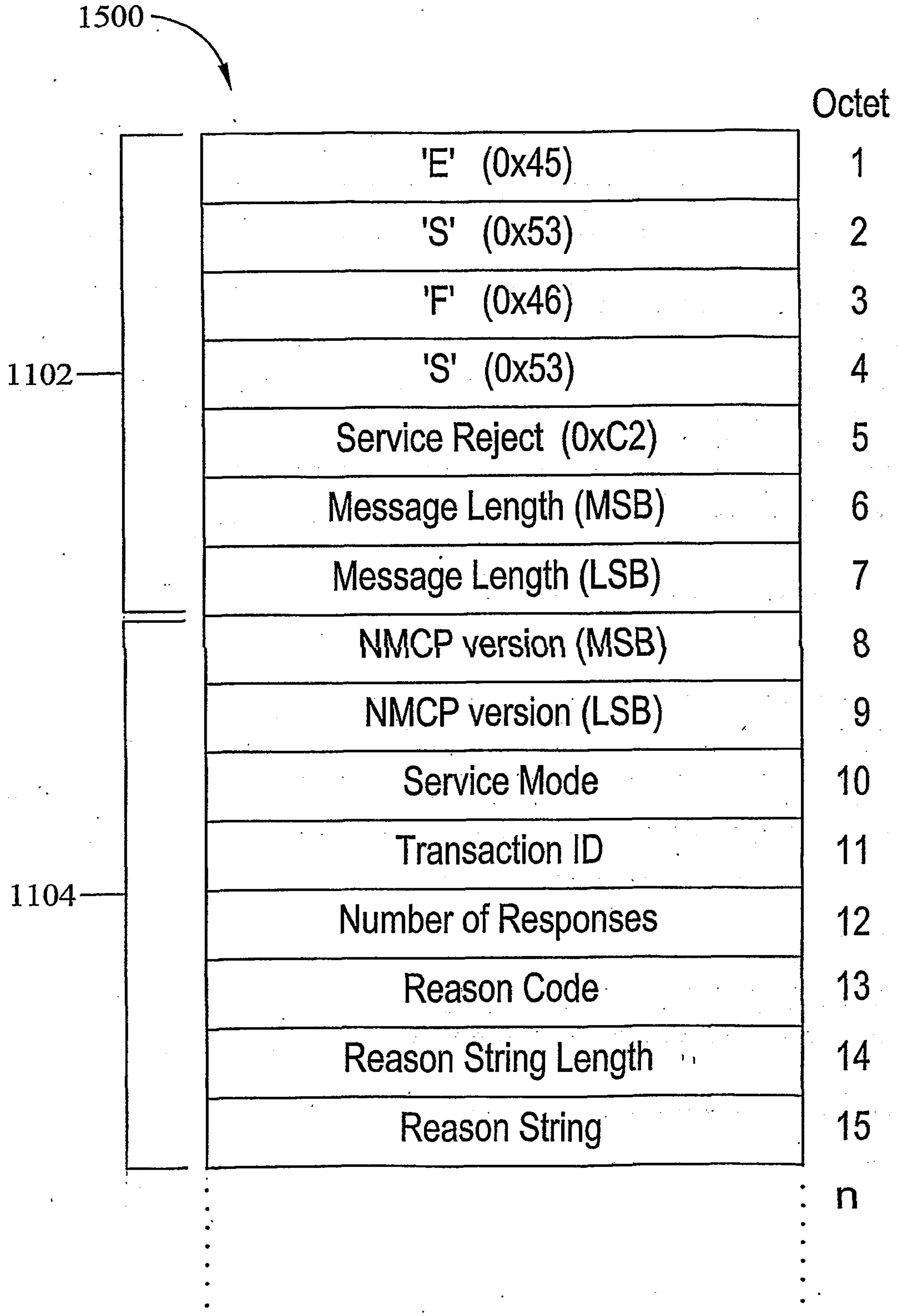

1300
Octet
'E' (0x45) 1
'S' (0x53) 2
'F' (0x46) 3
'S' (0x53) 4
Service Request (0x02) 5
Message Length (MSB) 6
Message Length (LSB) 7
NMCP version (MSB) 8
NMCP version (LSB) 9
Card ID (MSB) 10
Card ID (LSB) 11
Card Port ID 12
Service Type 13
Transaction ID 14
Service Data
1102
Service Type = LINK
Link Type 15
Link Interface 16
NEPC (MSB) 17
NEPC (octet 2) 18
NEPC (octet 3) 19
NEPC (LSB) 20
FEPC (MSB) 21
FEPC (octet 2) 22
FEPC (octet 3) 23
FEPC (LSB) 24
Signaling Standard 25
Link Set Name String Length 26
Link Set Name String 27 + n
Link Set Name String ...
CLLI String Length
CLLI String
CLLI String ...
1104
Service Type = SYS_ALARM
CLLI String Length 15
CLLI String 16
CLLI String ... 17 + n

FIG. 13



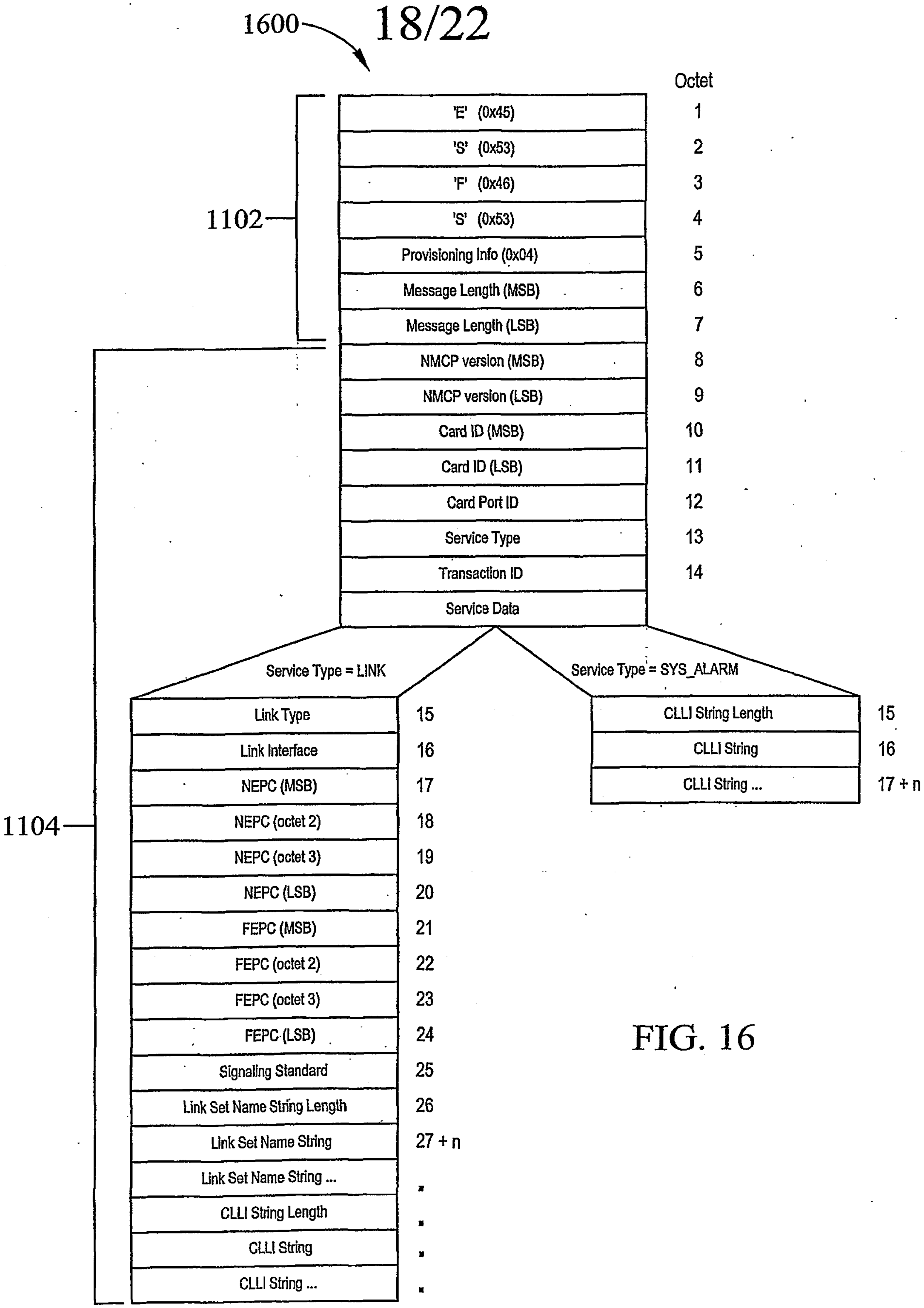
	Octet
'E' (0x45)	1
'S' (0x53)	2
'F' (0x46)	3
'S' (0x53)	4
Service Accept (0x82)	5
Message Length (MSB)	6
Message Length (LSB)	7
NMCP version (MSB)	8
NMCP version (LSB)	9
Service Mode	10
Transaction ID	11
Number of Responses	12
IP Address (MSB)	13
IP Address (octet 2)	14
IP Address (octet 3)	15
IP Address (LSB)	16
TCP Port (MSB)	17
TCP Port (LSB)	18

FIG. 14



	Octet
'E' (0x45)	1
'S' (0x53)	2
'F' (0x46)	3
'S' (0x53)	4
Service Reject (0xC2)	5
Message Length (MSB)	6
Message Length (LSB)	7
NMCP version (MSB)	8
NMCP version (LSB)	9
Service Mode	10
Transaction ID	11
Number of Responses	12
Reason Code	13
Reason String Length	14
Reason String	15
	n

FIG. 15



	Octet
'E' (0x45)	1
'S' (0x53)	2
'F' (0x46)	3
'S' (0x53)	4
Provisioning Info (0x04)	5
Message Length (MSB)	6
Message Length (LSB)	7
NMCP version (MSB)	8
NMCP version (LSB)	9
Card ID (MSB)	10
Card ID (LSB)	11
Card Port ID	12
Service Type	13
Transaction ID	14
Service Data	

Service Type = LINK

Link Type	15
Link Interface	16
NEPC (MSB)	17
NEPC (octet 2)	18
NEPC (octet 3)	19
NEPC (LSB)	20
FEPC (MSB)	21
FEPC (octet 2)	22
FEPC (octet 3)	23
FEPC (LSB)	24
Signaling Standard	25
Link Set Name String Length	26
Link Set Name String	27 + n
Link Set Name String ...	.
CLLI String Length	.
CLLI String	.
CLLI String ...	.

Service Type = SYS_ALARM

CLLI String Length	15
CLLI String	16
CLLI String ...	17 + n

FIG. 16

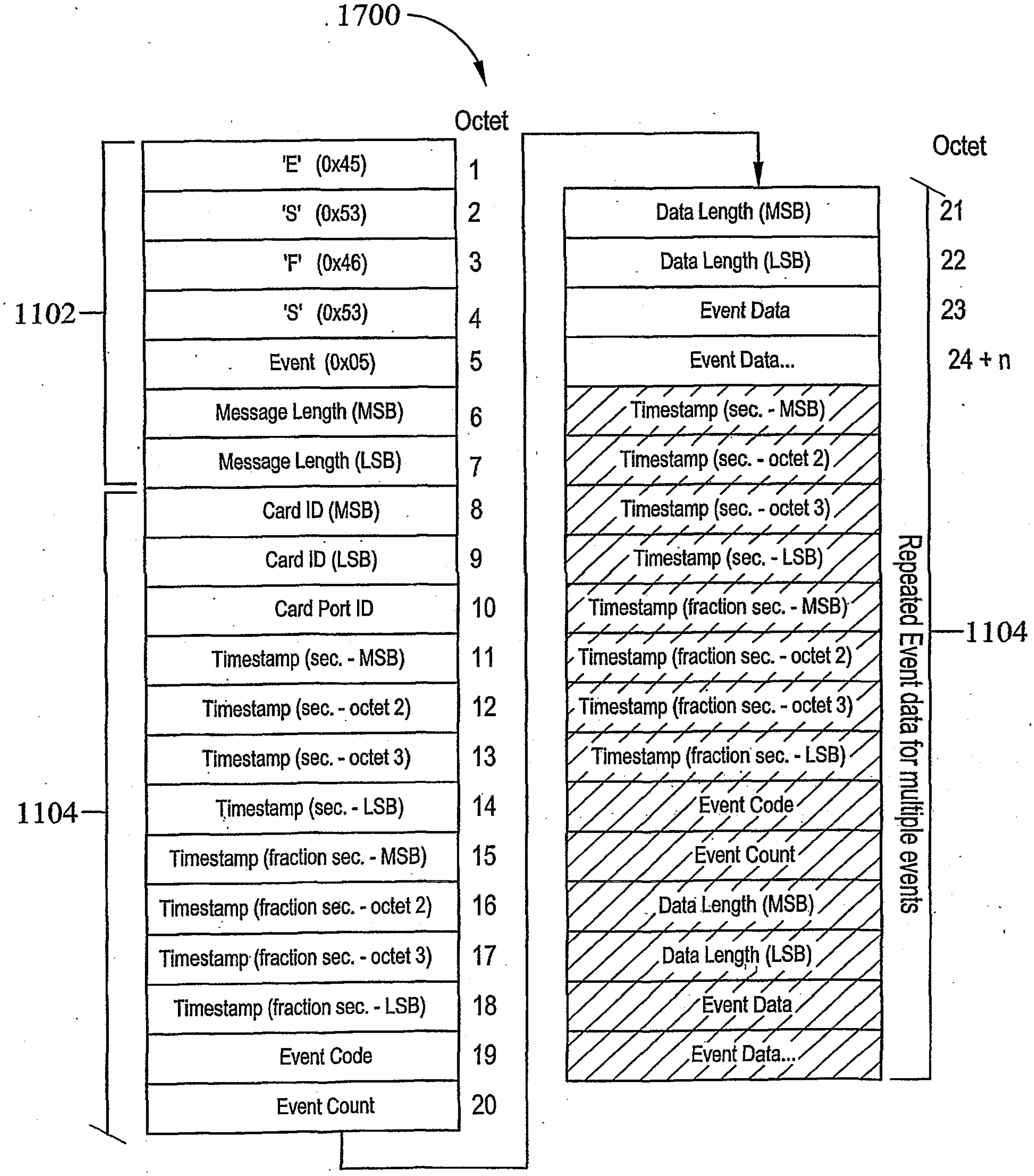
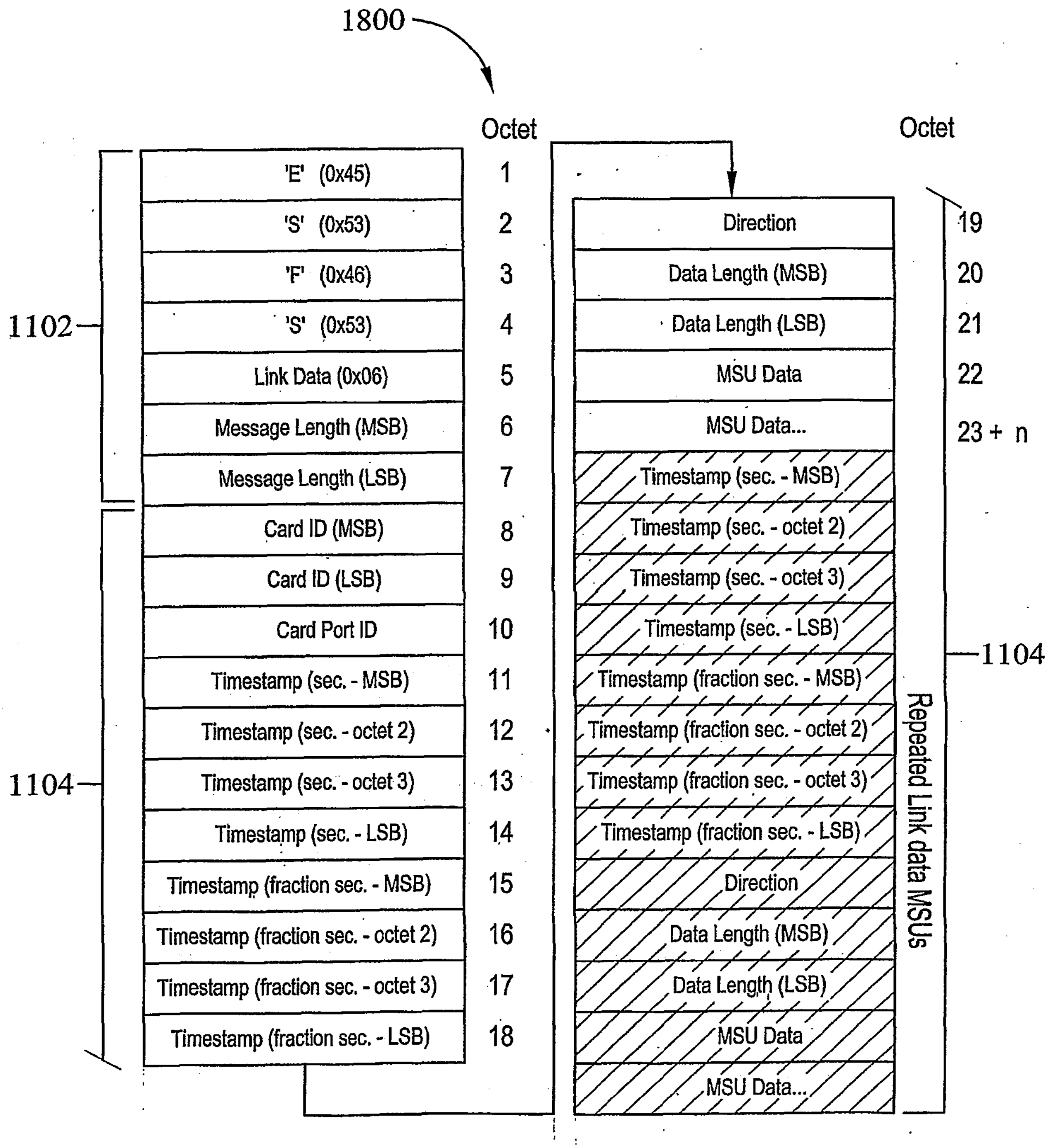
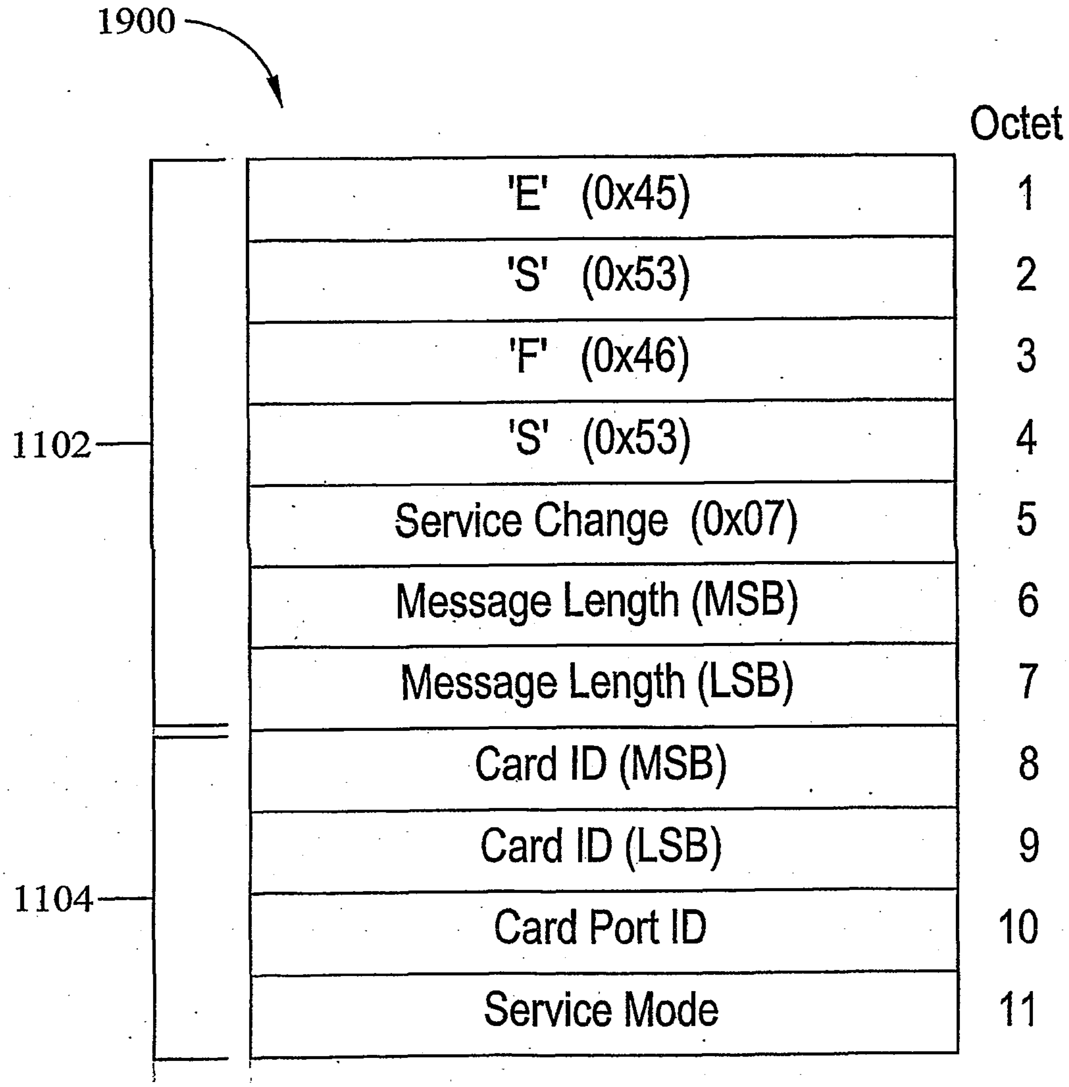

1700
Octet
'E' (0x45)
1
'S' (0x53)
2
'F' (0x46)
3
'S' (0x53)
4
Event (0x05)
5
Message Length (MSB)
6
Message Length (LSB)
7
Card ID (MSB)
8
Card ID (LSB)
9
Card Port ID
10
Timestamp (sec. - MSB)
11
Timestamp (sec. - octet 2)
12
Timestamp (sec. - octet 3)
13
Timestamp (sec. - LSB)
14
Timestamp (fraction sec. - MSB)
15
Timestamp (fraction sec. - octet 2)
16
Timestamp (fraction sec. - octet 3)
17
Timestamp (fraction sec. - LSB)
18
Event Code
19
Event Count
20
1102
1104
Octet
Data Length (MSB)
21
Data Length (LSB)
22
Event Data
23
Event Data...
24 + n
Timestamp (sec. - MSB)
Timestamp (sec. - octet 2)
Timestamp (sec. - octet 3)
Timestamp (sec. - LSB)
Timestamp (fraction sec. - MSB)
Timestamp (fraction sec. - octet 2)
Timestamp (fraction sec. - octet 3)
Timestamp (fraction sec. - LSB)
Event Code
Event Count
Data Length (MSB)
Data Length (LSB)
Event Data
Event Data...
Repeated Event data for multiple events
1104

FIG. 17



Octet		Octet	
'E' (0x45)	1	Direction	19
'S' (0x53)	2	Data Length (MSB)	20
'F' (0x46)	3	Data Length (LSB)	21
'S' (0x53)	4	MSU Data	22
Link Data (0x06)	5	MSU Data...	23 + n
Message Length (MSB)	6	Timestamp (sec. - MSB)	
Message Length (LSB)	7	Timestamp (sec. - octet 2)	
Card ID (MSB)	8	Timestamp (sec. - octet 3)	
Card ID (LSB)	9	Timestamp (sec. - LSB)	
Card Port ID	10	Timestamp (fraction sec. - MSB)	
Timestamp (sec. - MSB)	11	Timestamp (fraction sec. - octet 2)	
Timestamp (sec. - octet 2)	12	Timestamp (fraction sec. - octet 3)	
Timestamp (sec. - octet 3)	13	Timestamp (fraction sec. - LSB)	
Timestamp (sec. - LSB)	14	Direction	
Timestamp (fraction sec. - MSB)	15	Data Length (MSB)	
Timestamp (fraction sec. - octet 2)	16	Data Length (LSB)	
Timestamp (fraction sec. - octet 3)	17	MSU Data	
Timestamp (fraction sec. - LSB)	18	MSU Data...	

FIG. 18



	Octet
'E' (0x45)	1
'S' (0x53)	2
'F' (0x46)	3
'S' (0x53)	4
Service Change (0x07)	5
Message Length (MSB)	6
Message Length (LSB)	7
Card ID (MSB)	8
Card ID (LSB)	9
Card Port ID	10
Service Mode	11

FIG. 19

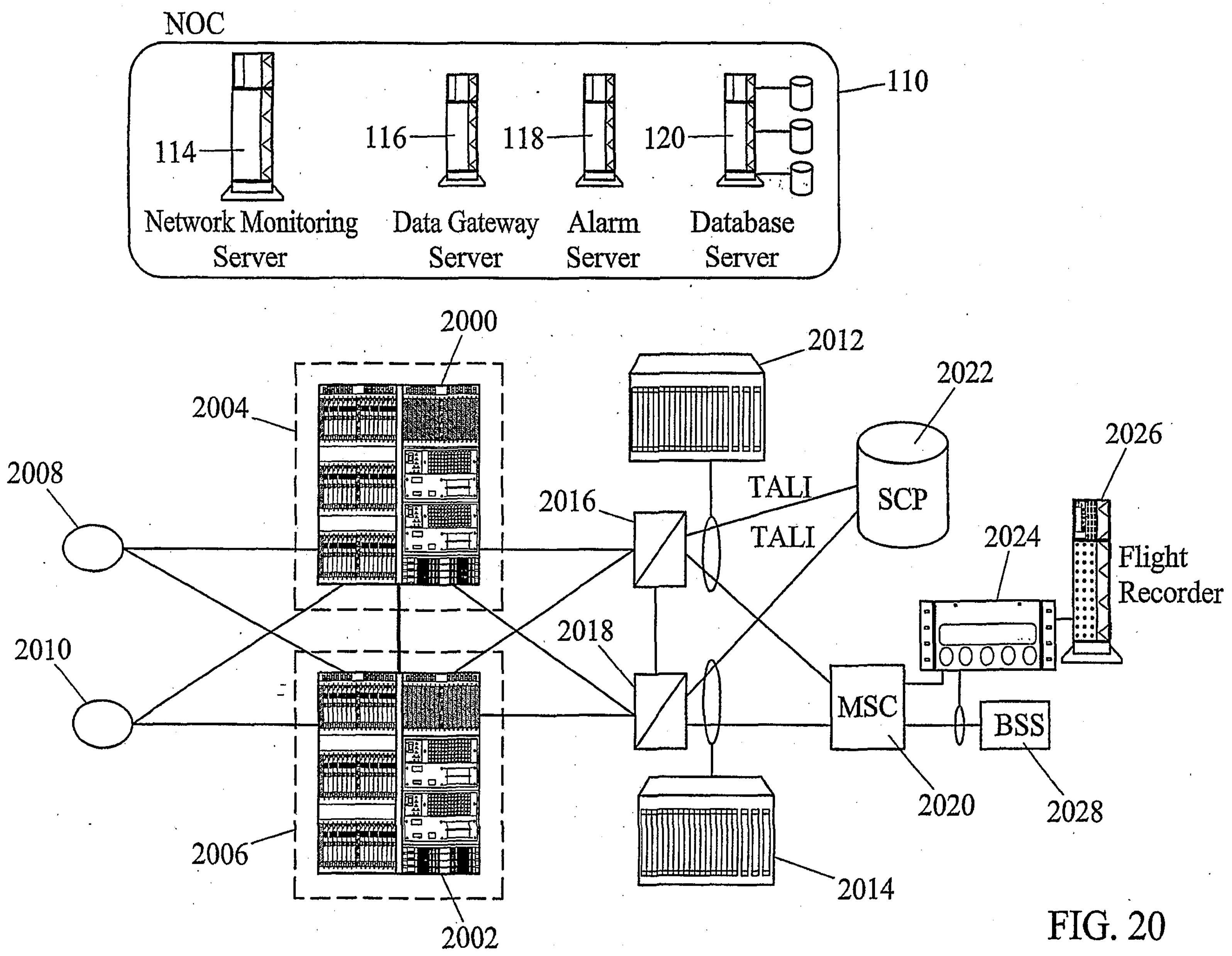

NOC
110
114
Network Monitoring Server
116
Data Gateway Server
118
Alarm Server
120
Database Server
2000
2004
2008
2010
2006
2002
2012
2016
2018
TALI
TALI
SCP
2022
2014
MSC
2020
BSS
2028
2024
2026
Flight Recorder

FIG. 20

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US02/16222

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G06F 9/44, G06F 13/00, G06F 17/00; H04Q 7/32
US CL : 709/223, 224; 703/23
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 709/223, 224; 703/23

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
None

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
East

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,889,954 A (GESSEL et al) 30 March 1999 (30.03.1999), column 3, lines 9-49.	1-45
Y	US 5,809,286 A (McLAIN, Jr. et al) 15 September 1998 (15.09.1998), column 3, lines 5-60.	1-45
Y	US 6,085,244 A (WOOKEY) 04 July 2000 (04.07.2000), column 2, lines 35-67; column 3, lines 1-18.	1-45
A	US 5,987,334 A (KAKU) 16 November 1999 (16.11.1999), column 2, lines 7-31.	1-45
A	US 6,167,446 A (LISTER et al) 26 December 2000 (26.12.2000), column 3, lines 40-67; column 4, lines 1-67.	1-45

□ Further documents are listed in the continuation of Box C. □ See patent family annex.

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"E" earlier application or patent published on or after the international filing date

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 08 July 2002 (08.07.2002)	Date of mailing of the international search report 07 AUG 2002
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Meng-Ai An for James R. Matthews Telephone No. (703)305-9669